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March 27 & 28, 2018 Building 9, Auditorium



Speaker & Poster ABSTRACTS

NOAA Fisheries West Coast Region 7600 Sand Point Way Northeast, Building 9 Seattle, Washington

Presented by Northwest Fisheries Science Center 2725 Montlake Boulevard East Seattle, WA 98112

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Speaker Abstracts

Session 1: Anthropogenic Influences

Tuesday, March 27, 8:30-10:30 am

Vanishingly low exposures to crude oil impact the development of a key forage fish species, Pacific herring (*Clupea pallasi*)

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Pacific herring are a critical component of North Pacific food webs, providing forage at all life stages for birds, marine mammals, and larger fish including Chinook salmon. In the past, they have also provided the basis of important commercial fisheries. The sensitivity of herring early life history stages to pollution was highlighted by the 1989 Exxon Valdez oil spill (EVOS) in Prince William Sound (PWS), Alaska. While insufficient data were obtained to unequivocally link the subsequent collapse of the PWS herring population to EVOS, studies prompted by the spill ultimately identified the herring heart as an exquisitely sensitive target of toxicity from polycyclic aromatic hydrocarbons (PAHs) in crude oil. We have been working to identify the lowest effective concentration of PAHs that impacts the developing herring heart, to link these effects to longterm impairment of growth and recruitment, and to develop molecular-diagnostic indicators that can be used to effectively monitor the impacts of future oils spills on this critical species. The remarkable translucence of nearly pigment-free herring larvae allows the use of simple digital videomicroscopy to obtain detailed measures of alterations in heart form and function by PAH exposure. Detailed analysis of cardiac phenotypes in herring, coupled with bioinformatics information from both model and non-model fish species, provided the basis for a large array of candidate indicator genes. We are in the process of elimination for linking altered expression of these candidates to oil-induced toxic effects. Promising candidates were identified that link altered levels of cardiac muscle structural protein to cardiac chamber dimensions. Additionally, using a marker for PAH exposure, cytochrome P4501A, we show that Pacific herring embryos are sensitive to concentrations below the limits of PAH detection by analytical chemistry. Our data establishes a no-effects concentration that is actually below background levels of PAHs in urbanized areas of Puget Sound.

Roads to ruin: The threats of urbanization to conservation of a sentinel species

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Urbanization poses a global threat to virtually all ecosystems, which is a challenge to species conservation. Our understanding of the impacts of anthropogenic ecosystem engineering is focused on physical habitat, as agricultural and forested lands are replaced with urban infrastructure. However, aquatic habitats are also chemically degraded by urban development, often in the form of toxic stormwater runoff. Since the late 1990s, coho salmon (Oncorhynchus kisutch) adults returning to their natal urban streams in Puget Sound experience high rates of spawner mortality syndrome. Evidence to date suggests that toxic urban stormwater runoff is the likely causative agent, and that this high mortality may pose a threat to wild coho populations. The ability to identify stream basins currently at risk for this syndrome is critical to conservation efforts. In this presentation, I will summarize our understanding of the landscape ecology of this syndrome across an urban gradient in the Puget Lowlands, based on analyses that identify relationships between in situ coho spawner mortality time series data and climate- and landscape-scale characteristics of the associated built environment. We found that the urbanization gradient was largely defined by road density and traffic intensity, among other variables, and positively related to mortality, which is consistent with other studies that suggest motor vehicles are the likely source of chemical mixtures that wash off urban landscapes into coho streams. We used the output from our statistical models to generate a predictive mortality risk map for the entire Puget Sound basin. The map identified likely hotspots for coho spawner die-offs in unmonitored basins across Puget Sound. Our analyses improve our understanding of the interplay between urbanization and climatic drivers of the mortality syndrome, are easily transferable to other regions, and can be used for siting green stormwater infrastructure in both the current built environment and future development scenarios.

Pacific salmon in hot water: Past, present, and future of thermal diversity in rivers

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Spatiotemporal variability is prevalent in natural thermal regimes within and among Pacific Northwest rivers, and salmon and steelhead are adapted to these diverse freshwater thermal landscapes. Projections about suitable freshwater habitats in the future are grim. Water temperature is expected to increase and summer flows to decrease, and there remains considerable uncertainty about how these changes will affect fish. We use a combination of spatially explicit empirical and modeled water temperatures, predicted changes in thermal and flow regimes, and simulated fish responses to evaluate risks for salmon posed by climate change. We illustrate that: 1) observed water temperature patterns are diverse at multiple spatiotemporal scales, 2) multiple methods of forecasting future thermal regimes yield more robust understanding, and 3) salmon may respond in unexpected ways to new thermal landscapes. We conclude that salmon populations most likely to be resilient to climate change will be those that have diverse thermal habitats available to them.

The fragmented fjord: Effects of large- and small-scale habitat modifications on aquatic bird communities in Puget Sound

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There have been marked declines in abundance for several marine bird and waterfowl species in Puget Sound and adjacent waters in recent decades. The causes of these declines are not well understood, but they likely include a variety of local and large-scale influences. While individual species and species groups are monitored throughout the greater Puget Sound, few analyses of local natural and anthropogenic influences on taxonomic composition have been done. We combined data from annual winter aerial bird surveys and GIS layers of physical shoreline structure and land cover to explore changes in marine bird and waterfowl assemblage composition across years, oceanographic sub-basins, and simple urbanization metrics in Puget Sound. Twenty-one years of annual winter surveys (1994–2014) were combined with data layers of land use and land cover adjacent to the shoreline. The best models using large-scale factors (year, oceanographic sub-basin), and local factors (% armoring or % urbanization) were generated through multiple model comparisons. We found concurrent effects of year and sub-basin on mean bird density in the best overall models for three feeding guilds (diving invertivores, diving piscivores, and opportunistic omnivores). In addition to large-scale patterns, there were effects of small-scale armoring and urbanization on mean bird density in the best overall models. These results document declining diversity in marine bird and waterfowl assemblages across the greater Puget Sound, and demonstrate that local anthropogenic factors can also influence bird density, presumably by affecting availability of food, foraging areas, or resting areas. Examining spatial relationships among these upper trophic-level consumers will not only improve our understanding of resident and migratory bird populations, but will also provide insights into both the dynamics of shoreline habitats throughout Puget Sound and potential anthropogenic impacts on the ecosystem.

Urban runoff and the integrity of Puget Sound food webs: Impacts to Pacific herring (*Clupea pallasi*) early life stages

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Pacific herring are a keystone species that spawn adhesive eggs on intertidal and shallow subtidal substrates. This nearshore spawning places sensitive life history stages (embryos and larvae) in close proximity to land-based, non-point source pollution such as urban stormwater runoff. Untreated urban runoff is chemically complex and highly toxic to aquatic life, including freshwater fish and invertebrates. However, very little is known about the impacts of urban runoff on nearshore marine fish. To examine the impacts of stormwater runoff on forage fish embryonic development, we exposed herring embryos to 0, 12, 25, or 50% stormwater runoff beginning just prior to the onset of a visible heartbeat (5 dpf) through hatching (11 dpf). Preliminary results indicate that stormwater exposures caused significant reductions in larval length and greater egg yolk area, consistent with a failure to mobilize embryonic energy stores (yolk). In addition, herring exposed to stormwater runoff exhibited cardiac injury including both functional (e.g., contractility) and morphological (e.g., increased atrium area) heart defects. The observed effects are consistent with the known cardiotoxicity of polycyclic aromatic hydrocarbons (PAHs) to fish embryos, and could result in delayed adverse outcomes such as reduced cardiorespiratory fitness and subsequent mortality.

Use of acoustic telemetry to assess impacts of the Hood Canal Bridge on migrating steelhead smolts

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The Hood Canal Bridge (HCB) spans the northern outlet of Hood Canal in Puget Sound, extends 15 feet underwater, and forms a barrier for steelhead (*Oncorhynchus mykiss*) migrating from Hood Canal to the Pacific Ocean. Acoustic telemetry studies performed from 2006–10 indicated substantial mortality and migration delays associated with the HCB, but fine-scale resolution of fish movement and behavior was needed to resolve the specific mechanisms around migration impediment. Individually coded acoustic telemetry transmitters implanted in juvenile steelhead were used in conjunction with an extensive array of receivers (Vemco VPS system) surrounding the HCB to obtain close approximations of the path each steelhead took as it encountered the bridge structure. Preliminary results of behavioral analysis indicate that steelhead smolts are utilizing the small openings under the east and west elevated segments of the HCB, as well as diving beneath the submerged pontoons, to migrate out of Hood Canal. Analysis of stationary tags (prolonged transmission at a single location) suggest that 33% (44/134) of the tags detected at the HCB remain within 1 km of the HCB as probable mortalities, while only one tag was detected stationary at the other four receiver arrays deployed. Instantaneous mortality rates within the 7-km segment containing the HCB were 6.8% and 8.6% per km for the two steelhead populations tagged, compared with 0.7% and 0.5% per km for the migration segment from the river mouth to the HCB. This study confirms the considerable impact of the HCB on steelhead smolt survival, and provides detailed information on what factors dictate successful or unsuccessful migration past the HCB.

Assessing persistent organic pollutant (POP) transfer from female killer whales (*Orcinus orca*) to calves during gestation and lactation

Dawn Noren*, Gina Ylitalo, Kristine Burtis, Daryle Boyd, Amy McCoy, Todd Schmitt, Steve Osborn, and Judy St. Leger

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Persistent organic pollutants (POPs) pose a health risk to Southern Resident killer whales (SRKWs). Data on maternal contaminant transfer to calves are needed to inform models that estimate future contaminant loads, as well as to assess risk to newborn killer whale calves exposed to POPs. In order to fill these data gaps, lipid content and POPs were quantified in blood serum (serum and blubber POP levels are highly correlated) collected several times during gestation, and in milk and blood serum collected every two weeks during the lactation period, from trained female killer whales. Serum samples were also collected from calves during the lactation period. POP concentrations in milk collected over 15 months postpartum from the primiparous female decreased by 47-65%, depending on the contaminant class. The highest influx of contaminants to calves tended to occur soon after birth. Greater contaminant transfer rates during early lactation were also reflected in maternal serum POP levels. POP levels in maternal serum decreased significantly during the first 144–158 days post-partum, depending on contaminant class, and then leveled off through the remaining lactation period. This resulted in 67–81% reductions in maternal serum POP levels over 15 months. By 15 months post-partum, serum POP levels from the primiparous female had dropped to initial levels measured in the multiparous female during pregnancy. Dissimilar to the multiparous female, body mass and blubber thickness in the primiparous female also declined significantly during the first 3-5 months post-partum, demonstrating linkages between lipid and POP transfer from blubber stores to milk in early lactation. By the end of lactation, lipid-corrected POP concentrations in serum from the firstborn calf were 5-8 times greater than the corresponding POP levels from her primiparous mother. These results demonstrate that very young neonatal SRKW calves, particularly firstborn calves, are at high risk from contaminant exposure.

Session 2: Little Critters in a Big Ocean Tuesday, March 27, 11:00 am-12:32 pm

Ocean avian predation on Columbia River salmon populations: What we know, what we don't know, and next steps to improve our knowledge

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In 2003, the NWFSC began to systematically strengthen our understanding of the early marine survival of juvenile salmon by looking at one potential source of ocean predation: seabirds. A four-step approach to addressing predation asked the following: 1) Which predator species are present during the early marine period? 2) Of these predators, which are abundant enough for a potential population-level impact? 3) When and where do salmon populations overlap in space and time with those predators? 4) To what extent, if any, does salmon consumption by seabirds impact population-level salmon survival? We now know that common murres (*Uria aalge*) and sooty shearwaters (*Ardenna grisea*) are abundant seabirds whose distributions overlap with at least six ESU/DPS groups of juvenile Columbia River Chinook salmon (Oncorhynchus tshawytscha) during May and June. Results from at-sea surveys, satellite telemetry, and models of predator-prey distributions demonstrate these predators are attracted to and aggregate in the Columbia River Plume region, a unique nearshore habitat directly affected by freshwater discharge from the river, and through which all outmigrating juvenile salmon must pass to successfully enter the ocean habitat. However, the quantitative diet data necessary to inform bioenergetic models or other theoretical approaches to estimate salmon predation are presently unavailable for murres or shearwaters in the Plume region. Ballpark estimates based on sparse diet data, as well as results from other systems where data are available, both suggest that predation impacts may be significant. If we assume that the times and locations of highest predator-prey overlap also represent the times and locations of highest potential mortality risk, then the next logical step is to quantify predation events in the field and estimate realized predation mortality. Completing the final steps in assessing the population impacts of predation will require integrating new empirical data with theoretical approaches to quantify predation mortality.

Temporal and spatial distribution of Azadinium spp. in the Salish Sea

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Azaspiracids are produced by species of dinoflagellate genera Azadinium and Amphidoma, and can cause a syndrome in humans called azaspiracid shellfish poisoning. In 1995, mussels from Ireland contaminated with azaspiracids were first linked to this human illness that includes symptoms of nausea, vomiting, severe diarrhea, and stomach cramps. Similar symptoms reported by consumers of Puget Sound shellfish, but with no detectable diarrhetic shellfish toxins or Vibrio contamination, motivated our study of the distribution of *Azadinium* species in Washington State. During the summer months of 2014–17, quantitative polymerase chain reaction (qPCR) analysis using probes specific to species of Azadinium from the North Sea detected the presence of Azadinium poporum, A. spinosum, and A. obesum at several SoundToxins sites in Puget Sound and on the outer coast of Washington State. In 2016 and 2017, standard curves developed using Azadinium isolates from Puget Sound (A. poporum) and the North Sea (A. spinosum and A. obesum) were used to quantify concentrations of up to 410, 250, and 150 cells L⁻¹ of A. poporum, A. obesum, and A. spinosum, respectively. In some samples where these three species were not detected, an Amphidomataceae-specific gPCR assay indicated that other species of Azadinium or Amphidoma were present. In addition, cultures of Azadinium species were established from sediment samples collected in Puget Sound, including A. obesum, A. cuneatum, A. poporum, and A. dalianense. The production of a new azaspiracid, named AZA-59, was confirmed by liquid chromatography mass spectroscopy in several isolates of A. poporum. Further work is needed to identify and isolate other species of Azadinium and/or Amphidoma and to develop qPCR probes for their detection and quantification. The identification of *Azadinium* species in the Salish Sea region demonstrates the need to assess their toxicity and to incorporate their routine detection into monitoring programs.

Water, water everywhere: Can eDNA from seawater provide insight into population genetic structure of small cetaceans?

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Determining management units is critical for the effective conservation and management of natural populations. Although research methodologies for collecting genetic samples are numerous, some species are particularly elusive, and conventional methods of tissue sampling have left critical gaps in population assessments. This is particularly true for the smallest cetaceans in the family Phocoenidae. One of the smallest cetaceans in the Northern Hemisphere, the harbor porpoise (Phocoena phocoena), is a primary example. Harbor porpoise are distributed throughout shallow coastal waters in the North Pacific. In Alaska, this preference for nearshore waters makes them highly vulnerable to incidental fisheries bycatch and the effects of habitat degradation. The nature and magnitude of incidental takes are currently unknown, but may be significant in some Alaska salmon (*Oncorhynchus* spp.) and Pacific herring (*Clupea pallasi*) fisheries. Concern for localized impact on undefined harbor porpoise stocks motivated population genetic analyses using archived tissue samples; however, sample sizes were severely limited in key geographic areas, and efforts to supplement strandings and fisheries bycatch with remotely collected tissue biopsies have proved challenging for these small, highly mobile, elusive cetaceans. By exploiting the naturally shed cellular debris in seawater and the power of next-generation sequencing, we developed a novel approach for generating population-level mitochondrial sequence data from environmental DNA (eDNA) using surface seawater samples. Using gPCR. we quantified harbor porpoise eDNA in 118 seawater samples and generated mitochondrial sequence data for 41 harbor porpoise eDNA samples using next-generation sequencing. These mtDNA haplotypes can be incorporated into a traditional framework for examining genetic diversity among harbor porpoise in the coastal waters of Southeast Alaska and evaluating evidence for stock structure. This indirect sampling tactic for characterizing stock structure of small and endangered marine mammals has the potential to revolutionize population assessment for otherwise inaccessible marine taxa.

Pseudo-nitzschia early warning bulletin increases shellfish harvest opportunities in the Pacific Northwest

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The 2015 coastwide bloom of toxic *Pseudo-nitzschia* resulted in over \$125 million losses to shellfish harvesters and contributed to the deaths of marine mammals. This event illustrated the need for shellfish managers to receive complete and timely information to allow them to plan for seasonal closures and to provide safe and timely harvest opportunities. Toward this end, a Pacific Northwest Harmful Algal Bloom (PNW HAB) Bulletin provides forecasts that help these resource managers from Neah Bay to Newport target their beachside monitoring of toxicity levels in shellfish and fine-tune decisions regarding closures of beaches to shellfish harvest. This forecast system will include sampling by the Makah Tribe and the NWFSC Newport lab at two documented offshore HAB hotspot sites, the Juan de Fuca eddy and Heceta Bank. These offshore HAB data will be combined with a wealth of other information sources: beachside monitoring by Olympic Region HAB (ORHAB) partners and the Oregon Department of Fish and Wildlife, the LiveOcean forecast model, and near real-time data from an offshore biological sensor (the Environmental Sample Processor). The first PNW HAB Bulletin, published in May 2017, gave managers confidence in their highly unusual decision to increase the daily limit from 15 to 25 razor clams per day. This significant increase in bag limit resulted in a record number of one-day digger trips and over \$5.3 million injected into the local economy. Future PNW HAB Bulletins will help coastal managers make rapid, informed decisions about seafood safety, and are planned to transition to operations starting in 2019.

Reconstructing the historical abundance of west coast Dungeness crab

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The Dungeness crab (*Metacarcinus magister*) fishery is one of the largest and most valuable fisheries on the U.S. West Coast. Though conventional wisdom suggests that the fishery takes the vast majority of legal-sized crab coastwide each year, this has not been demonstrated empirically. We use catch data from landings receipts and logbooks in combination with a depletion estimator approach to estimate preseason abundance from 1970–2016 (California) and 1982–2016 (Oregon and Washington). We find that the fishery takes approximately 30–100% of the legal-sized male population each year, averaging ~92% in the last decade. Though slightly different patterns of depletion are shown in logbooks and landings receipts, estimates of preseason abundance are consistent across data sources. In spite of the high rate of exploitation, the population appears to be stable or increasing in the long term. In Central/Southern California, the abundance has shown a particularly rapid increase over the past decade after a long period of low abundance, potentially due to changing oceanographic conditions.

Monitoring the migrations of wild Snake River spring/summer Chinook salmon juveniles

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Since 1991, NOAA Fisheries has monitored migration timing, growth, and estimated parr-to-smolt survival rates for wild spring/summer Chinook salmon (*Oncorhynchus tshawytscha*) from the Salmon River basin to the lower Snake River. During July through August each summer, fish are collected from up to 16 sampling sites and subsequently tagged using passive integrated transponder (PIT) tags. As fish migrate from their native streams in the headwaters of the Salmon River in Idaho, data are collected on in-stream PIT arrays, smolt traps, and detection within juvenile bypass systems at the Federal Columbia River Power System (FCRPS) dams on the Snake and Columbia Rivers. From 1993–2017, estimated parr-to-smolt survival to Lower Granite Dam has ranged from 8–25% (yearly average 14.9%) for all streams combined. Although parr-to-smolt survival is based on a number of different factors, a direct effect is parr density. For years with low parr densities, the trend is for higher parr-to-smolt survival (24.4% in 1998), while for years of high parr densities, parr-to-smolt survival tends to be low (8.1% in 2004). Growth of individuals has proven to be positively related to elapsed time between tagging and recapture, and negatively related to fork length at time of tagging. Passage of the middle 80% of fish at Lower Granite Dam has ranged from 22–55 days (average 35 days) for the combined wild populations since 1991. Data provided by this project establish a foundation for understanding ecological factors that play a critical role in the recovery of threatened and endangered wild Snake River spring/summer Chinook salmon.

Uncovering mechanisms of ocean change effects on Dungeness crab through metabolomics analysis

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The Dungeness crab (*Metacarcinus magister*) is an economically, ecologically, and culturally important species distributed along the North American Pacific coast. In the U.S. Pacific Northwest, where their population density is highest, Dungeness crab will face more extreme global ocean change conditions, since the region is already naturally more acidic than the global ocean. However, it is not known how sensitive the Dungeness crab is to ocean acidification and limited dissolved oxygen (DO), a compounding co-occurring phenomenon. Our past lab experiments have shown reduced survival and delayed development in Dungeness crab larvae exposed to high CO₂ conditions, but the mechanisms underlying these responses are not clear. To further investigate this, we used untargeted metabolomics approaches to characterize metabolite and lipid profiles in individual Dungeness crab larvae reared in pH x DO treatments that mimicked current and projected future conditions. We show larvae metabolic response to low DO differs from pH response, affecting the abundances of a larger number of metabolites and lipids. Despite limited metabolome annotation and high variation within treatment groups, our study elucidates logical physiological pathways potentially affected by ocean acidification and expands our overall understanding of how the species might respond to future ocean conditions.

The effects of pH, dissolved oxygen, and temperature on larval and juvenile Dungeness crab

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Dungeness crab (*Metacarcinus magister*), the most economically valuable fishery on the U.S. West Coast, are potentially vulnerable to ocean acidification. In previous studies, Dungeness crab zoea had a lower survival and slower developmental rate when reared in low pH (high CO₂) water. Using our Mobile Ocean Acidification Treatment System (MOATS), we tested the response of zoea, megalopae, and early juveniles in a combination of pH, temperature, and dissolved oxygen (DO) treatments that mimic current and potential future conditions under climate change. In the zoea experiments, adult Dungeness crabs with eggs were collected from Puget Sound and held at our field station in Mukilteo, Washington. Newly hatched zoea where then placed in replicate pH x temperature treatments (2015) or pH x DO treatments (2016). Zoea were reared in treatment conditions for 30–45 days, depending on experiment. In the megalopae-to-early-juvenile experiments, wild megalopae were collected from light traps in Puget Sound and reared in pH x DO treatments (2015 and 2016) through the second juvenile instar stage. We observed effects on survival, development rate, and growth. In general, temperature and DO produced greater deleterious effects than pH treatments, suggesting that these aspects of climate change may pose a greater potential risk to Dungeness crab populations in some locations than ocean acidification.

Session 3: Physical Habitat and New Technologies Tuesday, March 27, 2:00–3:32 pm

Do juvenile coho salmon and steelhead trout prefer to jump over or swim around beaver dams? The results may surprise you

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Increasing the availability of slow-water overwintering habitat is crucial to the recovery of ESA-listed coho salmon (*Oncorhynchus kisutch*) stocks in California and Oregon. Under natural conditions, such slow-water habitat is often formed by beaver dams, but there is concern that beaver dams present a barrier to movement, particularly for juvenile salmonids. Using passive integrated transponder (PIT) technology, we field tested the ability of juvenile coho salmon and steelhead trout (*O. mykiss*) to cross beaver dams. We tested the preferred pathway for each species, assessing whether they preferred to jump over or swim around the dams, the velocities and jump heights that they accommodated, and the timing of movements. The results provide fresh insights to regulators and stream restoration practitioners who are working to improve freshwater habitat conditions for salmonids.

Juvenile salmon rearing capacity of the Columbia River basin: A geomorphic approach to estimating large-scale habitat availability and floodplain restoration opportunities

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Historically low abundances of Columbia River basin (CRB) salmon have persisted despite restoration and policy actions spanning decades. To better evaluate the magnitude of freshwater habitat loss and likely benefits of large-scale river floodplain restoration, we used a geomorphic approach to estimate rearing capacity for spring-run Chinook salmon (*Oncorhynchus tshawytscha*) at the sub-basin spatial scale (HUC-8) throughout the CRB. We measured satellite imagery for main stem and off-channel habitat areas throughout the CRB at randomly selected sites stratified by land use, stream size, and estimated channel form. These measurements were used in a series of random forest models to separately predict side-channel and mainstem area at each 200-m stream segment with geomorphic and land-cover predictors (land cover, floodplain width, slope, sinuosity, discharge, sediment accumulation, elevation, and bankfull width). For each sub-basin, we summed the estimated rearing habitat as well as distinct habitat types: side channels, main stem banks, main stem bars, and midchannel reaches. Midsummer parr capacity was estimated by applying literature-derived parr capacity densities to each individual habitat type. Historical estimates of side-channel habitat indicate an area loss of ~26%, which varies regionally. Although floodplain reconnection can be a costly restoration tool, we find that the dynamism of stream channels and diversity of habitats could likely be returned with connection of a small portion of the historical floodplain. Moreover, restoration in cropland and rangeland alone could improve rearing capacity by ~9%. Future improvements include higher-resolution estimates of floodplains and geomorphic attributes, and automated stream habitat classification with multispectral satellite imagery.

Puget Sound Habitat Status and Trends Monitoring Program: Nearshore and delta geospatial data and habitat status and trends monitoring metrics

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The Puget Sound Habitat Status and Trends Monitoring (PSHSTM) Program was developed to provide consistent salmon habitat status and trends data to support status reviews of ESA-listed salmon populations. Our approach relies on readily available and regularly updated aerial imagery to consistently map key habitat features at a regional scale across major population groups. We developed a census-based approach to map key habitat features throughout the nearshore, delta, floodplain, and large river environments across Puget Sound. In the nearshore environment, we are mapping overwater structures (e.g., docks, piers, bridges, buoys/floats, booms, aquaculture, and boat ramps), forested shoreline, and small embayment habitat features (e.g., lagoons, pocket estuaries, and blind tidal channels) for all ~4,000 km of Puget Sound's shoreline. In the delta environment, we are mapping tidal wetland areas, geomorphic delta boundaries, and channel features (e.g., distributaries and tidal channels) for all 17 deltas that drain into Puget Sound, Hood Canal, and the Strait of Juan de Fuca. In the floodplain and large river habitats, we are mapping floodplain boundaries, channel features (e.g., main, braid, and side channels), and wood jams for all large river systems in Puget Sound. This presentation will provide an overview of our mapping efforts in these environments, and a demonstration of how the metrics derived from this monitoring effort can be related to key Viable Salmon Population (VSP) parameters. Our results suggests that the consistent regional-scale geospatial data sets developed from these efforts can be used to support ESA status reviews of listed salmon populations. We are also sharing data and GIS products produced from the PSHSTM Program through the Puget Sound Partnership, which will allow our efforts to support other research and management needs that can benefit from consistent regional-scale habitat status and trends data.

Impact of fish feeds, fish oils, and amino acids on the performance of airlift pumps

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Airlift pumps are widely used in aquaculture for pumping, pond mixing, aeration/degassing, and carbon dioxide removal. Compared to mechanical pumps, airlift pumps have lower initial costs, lower maintenance, easy installation, portability. freedom from clogging, small space requirements, simplicity of design, ease of construction, greater efficiencies when operated at low head and high submergence, easily regulated flow rates, and high versatility of application. Research focused on reducing energy consumption, production costs, and greenhouse gas emissions from reuse systems is of great interest in aquacultural engineering. Key to this research is the reduction of pump head requirements and improvement of the efficiency of aeration/degassing processes. In production marine reuse systems, a significant decrease in airlift pump flowrate was visually observed immediately after feeding. The impact of the addition of a wide variety of commercial. experimental, larval feeds as well as fish oils, specific lipid products, amino acids, and surfactants on airlift pumping rates was evaluated. At 250 minutes after feed addition, the airlift flow rate varied from 12-102% of base flow. As a group, the fish and algal-based oils had the greatest impact on airlift flow rate. There was a significant correlation between gas holdup and airlift pumping rate. Higher gas holdup was positively correlated with higher water flows. There was also a wide range in speed and flow rate recovery: flow recovery may depend on adsorption of lipids on the tank walls or chemical reactions. There was a positive correlation between lipid content and flow reduction, but the physical characteristics of the feed and specific fatty acid profiles of the feed may be important. The use of performance information based on clean water tests may significantly overestimate pumping rates of airlift pumps.

Quantifying variation in killer whale (*Orcinus orca*) morphology using elliptical Fourier analysis

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In the northeastern Pacific Ocean, there are three "ecotypes" of killer whales that differ in diet, ecology, behavior, acoustics, genetics, and morphology. Previous attempts to describe the morphological differences among populations of killer whales ($Orcinus\ orca$) have been limited to descriptive accounts or categorical studies. We used elliptical Fourier analysis (EFA) to quantify shape differences of dorsal fins and pigmentation patterns among the ecotypes from photo-identification data of more than 500 individuals. Variations in shapes of the dorsal fin, saddle patch, and eye patch were successfully quantified using EFA, and there were highly significant (P < 0.01) differences among the ecotypes in all three morphological traits. The ability of EFA to discriminate ecotypes based on dorsal fin and eye-patch shapes was substantial, though it did not perform as well for saddle patches. Visualization of the shape variation along principal component axes mirrored previous descriptions of the differences among ecotypes. Although the degree of inheritance of morphology in killer whales has not been determined, these results are consistent with the conclusion that there is a high degree of reproductive isolation among the ecotypes, and introduce elliptical Fourier analysis to the study of cetacean morphometrics.

Characterizing the ocean distribution of ESA-listed salmonids with pop-up satellite tags: Implications for Southern Resident killer whale conservation

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Improved understanding of salmon distributions will benefit efforts to conserve both salmon and the Southern Resident killer whales (SRKW: Orcinus orca) that prev on them. Specifically, the overlap of SRKW and salmon in space and time affects the distribution and effort expended by foraging killer whales, and the resulting impact on salmon survival. The reevaluation of the 1938 Mitchell Act hatcheries proposed a reduction in the number of fall-run tule salmon (*Oncorhynchus* tshawytscha) raised at hatcheries in the lower Columbia River, and an increase in production at Bonneville Dam to mitigate the reduction downstream. One of the most important considerations is the potential reduction in salmon available to SRKW. To develop a better understanding of the overlap between salmonids and killer whales, we plan to tag salmonids with popup satellite tags (PSTs) which will allow us to document their marine movement patterns. When combined with remotely sensed and modeled oceanographic data, we can characterize the conditions tagged fish experience. This technology will result in more precise and comprehensive distribution information, improving assessments of salmon distribution in ocean and coastal environments. To maximize success, we propose to focus our initial efforts on threatened steelhead (0. mykiss) populations. Adult steelhead that return to sea after spawning (kelts; >400 mm fork length) will be obtained from kelt reconditioning ponds and outfitted with PSTs that record temperature, depth, light, and location information, Kelts have a high probability of surviving for a year or more in the marine environment. Moreover, as full-grown adults, these fish are large enough to be ideal killer whale prey. There are currently multiple efforts to reduce the size of pop-up satellite tags. Smaller tags will allow us to tag smaller individuals. In the future, we plan to tag additional salmonid species, such as bull trout and subadult and prespawning Chinook salmon.

Estuary to Bonneville survival of radio-tagged adult spring/summer Chinook salmon in 2016 and 2017

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In 2016 and 2017, as part of an ongoing PIT tag study estimating survival and run timing of spring/summer Chinook salmon (*Oncorhynchus tshawytscha*) from the Columbia River estuary to Bonneville Dam, a subset of 100 PIT-tagged fish were also tagged with 30 MHz VHF radio transmitters by gastric implant. Fish were captured via tangle net from late March to early May near rkm 40 in the Columbia River and fish movements were tracked using 20 fixed-site antenna locations between Pillar Rock (rkm 43) and Bonneville Dam (rkm 234). Over the two study years, patterns emerged in reach survival. Survival was low in the lowermost and uppermost reaches in comparison to the almost 150 kilometers of "middle" reaches in the study area. From release (rkm 40) to Mayger, OR (rkm 85), survival was 0.84 and 0.67 in 2016 and 2017 respectively. Survival from the Bonneville tailrace radiotelemetry sites (rkm 231) to the Bonneville adult fish ladder PIT-tag detectors (rkm 234) was 0.78 both years. The first two study years saw extreme differences in flow; average flows during the study period were 264 and 412 kcfs in 2016 and 2017 respectively. Differences in flow appeared to impact travel times throughout all study reaches, increasing exposure time to harvest and predation. Median travel time from release to passage at Bonneville Dam in 2017 was twice that of 2016, 34 compared to 17 days. In 2017, average tailrace delay, measured from the Bonneville Dam radiotelemetry sites in the tailrace to the adult fish ladders, tripled from 2 to 6 days. This study will add a third year of data in 2018, providing another much-needed data set and likely adding consistency to the data with respect to river conditions experienced by fish over three study years.

Catch shares management: Implications for species without quotas

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Bycatch occurs when fishermen's catch includes that which they cannot or do not want to retain, often resulting in atsea discards and wasted ecological and economic resources. In 2011, catch shares (CS) management was implemented in the west coast groundfish bottom trawl sector to address a range of issues, including the high bycatch and discard rates typical of multispecies fisheries. As part of the required Five-Year Catch Shares Program Review, we examined the environmental performance of this management using West Coast Groundfish Observer Program data from 2004-16. We analyzed changes in discard amount and proportion for species managed using quotas, including those historically overfished. In addition, we explored impacts on non-quota species by examining discard of species included in the Pacific Coast Groundfish Fishery Management Plan (FMP) but not managed under the CS Program, as well as species not actively managed. We found that discard amounts decreased for all species starting in 2004 and declined to historic lows in 2011. following CS implementation. Discard amounts remained low through 2016, with much less interannual variability. Trends in discard proportion, however, were more variable. Discard of species managed with quotas dropped to a mean of 6% of catch after the implementation of CS (compared to 20% in the seven years prior). Similarly, discard of non-quota FMP species decreased from a mean of 62% prior to CS to a mean of 37%. An average of 97% of unmanaged species catch was discarded; this remained unchanged from 2004 to 2016. These findings document the expected results of decreased discard amounts and proportions of quota species, while pointing to additional benefits for both managed and unmanaged species. In the future, we can improve our understanding of the mechanisms behind these changes and use these results to move management of the fishery toward explicitly ecosystem-based methods.

Session 4: Fisheries Management and Monitoring Wednesday, March 28, 8:30–10:37 am

The EBFM Road Map, the IEA, and transformational ideas: Where do we all fit in?

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As a discipline, as an agency, and as a Fisheries Science Center, we have seen a considerable push toward incorporating ecosystem-scale approaches into our work as fisheries scientists. For some of us, this feels welcomed; others of us may feel differently and view the push as vague, unnecessary, or even threatening. And very likely for all of us in NOAA Fisheries, at times it feels confusing as new acronyms and new initiatives are introduced, often in rapid succession and without a clear explanation of how, if at all, they are connected. In this presentation, I will offer a brief perspective on where I see the linkages between three of the more well known, NOAA-endorsed tools and concepts intended to support ecosystem-based fisheries management (EBFM), namely the EBFM Road Map, the Integrated Ecosystem Assessment (IEA) framework, and the more recent call from headquarters for Centers to develop "transformational ideas." I will reflect briefly on my involvement with each of these concepts and how I see them fitting together and complementing one another. Finally, I hope to offer some assurance that these frameworks and initiatives have great potential for us as individual scientists, and for our field as a whole.

Associations between fish length, dam passage history, and adult return for Snake River yearling Chinook and steelhead

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Stocks of threatened or endangered Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) originating in the Snake River basin must pass through a series of eight major hydroelectric dams during their seaward migration. Various passage routes exist at each dam, and each differs in its risk of direct mortality. It is of interest to know whether passage through particular routes may impose lasting effects which may increase mortality risk upon entry to the estuary or ocean. Juvenile bypass systems are designed to divert fish away from turbine intakes via diversion screens and a system of pipes that lead to the dam tailrace. Fish may be exposed to trauma, increased stress, or disease in these bypass systems. Bypass systems are also one of the only routes at a dam equipped for detection of passive integrated transponder (PIT) tags. Our interest was in testing whether passage through bypass systems was associated with probability of returning as an adult after accounting for fish length and other covariates. We also investigated the association between fish length and probability of bypass at each dam. We used PIT-tagged fish that were known alive after leaving the last dam in the hydropower system to investigate any remaining mortality risk associated with passage history through bypass systems. We found that bypass probability was strongly associated with fish length at five of the seven study dams for both species. We also found that fish length was strongly associated with adult return, but bypass history had weak-to-no association with adult return after accounting for length. These results suggest that bypass passage has little effect on fish mortality relative to other passage routes after fish leave the hydropower system, and our findings underscore the importance of accounting for fish size in studies of dam passage or survival.

Shore-based processor outcomes under catch shares

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Fishery management measures often aim to regulate harvesting behavior but can have downstream effects on fish processors, output markets, and consumers. Empirical analysis of these impacts is generally limited due to data availability. Utilizing census costs and earnings data, we examine the operational characteristics and economic outcomes for shorebased processors before and after participating in the West Coast Groundfish Trawl Catch Shares Program, including consolidation, seasonal timing of fish purchases, costs, and net revenues. Projected impacts differed for processing of Pacific hake (*Merluccius productus*) and non-hake groundfish given the differences in fishery stocks, production processes, end markets, and management measures both pre- and post-catch share implementation. The complexity of the program allows us to leverage these distinctions to compare processor outcomes across the respective transitions to catch shares in each fishery. We find increased consolidation, lengthened seasonal operations, and increased net revenue for Pacific hake processors, and decreased delivery days, higher output prices, and increased costs as a percentage of revenue for non-hake groundfish processors. This study marks an important contribution to limited empirical work focusing on fish processors that comprise an important sector of the fishery and are an integral part of the seafood supply chain and the economic resilience of coastal fishing communities.

Management strategy evaluation for ecosystem-based fisheries management: Climate, food webs, and people

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Revealing tradeoffs among objectives is a key step in Management Strategy Evaluation (MSE). Yet, in the context of ecosystem-based fisheries management (EBFM), balancing complexity and simplicity in objectives, performance indicators, management strategies, and operating and estimation models can be a challenge. In this talk, I will compare the application of EBFM principles in two MSE-related projects focusing on fisheries with differing social and ecological contexts. Pacific hake (*Merluccius productus*) is an abundant migratory groundfish, managed under an international treaty between the U.S. and Canada. Growing recognition that environmental drivers may influence the age-dependent movement of hake raises concerns that spatial population structure could affect harvest rates in both countries. Pacific herring (*Clupea pallasii*) is an important cultural, economic, and ecological resource along the west coast of North America, and central to recent management conflicts in Canada. Using these examples, I illustrate how an MSE approach can reveal or hide social and ecological tradeoffs, depending on the scale at which objectives and performance indicators are set and the types of management strategies, operating models, and uncertainties that are considered. This work demonstrates the adaptability of applying EBFM principles through an MSE approach to tackle challenging problems in fisheries management.

Estimating predation risk of juvenile salmon near the Columbia River plume

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Predation is thought to impact salmonids during early marine residence, but a thorough understanding of the conditions under which predation occurs remains incomplete. Predation risk is predicted to be greatest when salmon and predators co-occur, as the probability of a smolt being encountered and eaten is highest. Encounter probability is determined primarily by co-occurring predators and prey, modified by biological and/or environmental conditions that influence prey detectability and densities of predators. The abundance and distribution of non-salmonid prev (i.e., forage fish) is hypothesized to reduce smolt predation by acting as a predation buffer (i.e., alternative prey hypothesis), or increase predation through apparent competition. The size of the Columbia River plume (CRP) influences densities of piscivorous common murres (Uria aalge) and sooty shearwaters (Ardenna griseus), and may also affect predation risk. We integrated research on juvenile salmon, forage fish, and seabirds near the CRP during 2010–12 to develop estimates of predator-prey co-occurrence and smolt predation risk. Murres and shearwaters co-occurred with smolts along the Washington coast at rates of 62% and 50%, respectively, similar to co-occurrence rates with acoustically detected forage fish (61% for murres, 46% for shearwaters). Smolt co-occurrence with murres was associated with decreasing salinity (i.e., CRP waters), whereas co-occurrence with shearwaters was associated with the abundance of other seabirds (i.e., local enhancement). Forage fish co-occurrence with both murres and shearwaters was also explained by the size of the CRP and local enhancement. Although forage fish co-occurred with smolts in 63% of surface trawls, there was no relationship between forage fish densities and seabird co-occurrence with smolts. These results suggest that CRP dynamics are a primary driver of predation risk, rather than densities of forage fish. Whether increased predation risk results in mortality and how these results relate to overall salmon population trends remain to be addressed.

Density-dependent and landscape effects upon estuary rearing in Chinook salmon: Insights from long-term monitoring in four Puget Sound estuaries

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Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) are well known for utilizing estuarine habitats within the tidal delta for rearing during outmigration. Several studies have linked population responses to availability of estuary habitat, and support the hypothesis that estuarine habitats are vital rearing areas for juvenile Chinook salmon. However, these coarse-scale studies provide little insight on how specific estuarine habitats contribute to rearing potential for salmon. We integrate long-term monitoring data from four estuaries of Puget Sound (Nooksack, Skagit, Snohomish, and Nisqually) to examine whether: 1) Chinook populations in these rivers are limited by restricted estuary habitat, 2) hatchery releases can influence density-dependent relationships in estuaries, 3) highly connected sites support higher densities of salmon, and 4) different habitat types support higher rearing densities of Chinook salmon. Across sampling locations within estuary systems, average annual rearing densities varied over four orders of magnitude. We found strong support for density dependence, habitat type, landscape connectivity, and hatchery release numbers influencing rearing densities, although all factors were not necessarily as important within each system, and effects of habitat type were particularly variable. Further work using bioenergetics models suggests that habitat-dependent variation in temperature can strongly influence growth in different systems, and that multiple habitats are likely important to provide suitable habitat for extended estuary rearing. These analyses are useful for determining the relative contribution of connectivity, cohort population size, and local habitat conditions for growth potential of Chinook salmon using estuarine habitats at early life stages.

Analysis of a multi-generational pedigree for Wenatchee River Chinook salmon: A work in progress

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We are examining a multi-generation pedigree of natural- and hatchery-origin Wenatchee River Chinook salmon (*Oncorhynchus tshawytscha*) with Bayesian generalized linear mixed models to estimate the genetic and environmental influences on variation in several life history traits in this population. We are also examining these data for evidence of natural selection on these traits, which include size, run timing, age, and lifetime reproductive success. This rapid-fire talk will go over the history of the population, the collection and organization of data for analysis, descriptions of the parameters we are looking at, and what we hope to learn when the analyses are complete.

Sociocultural and economic impacts of harmful algal blooms in coastal communities

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In 2015, a massive harmful algal bloom (HAB) of diatoms in the genus *Pseudo-nitzschia* hit the U.S. West Coast. The bloom, unprecedented in its toxicity and geographic extent, contaminated seafood resources with a toxin called domoic acid, necessitating fisheries harvest closures to prevent human illnesses. Extended and widespread closures of the lucrative commercial Dungeness crab (*Metacarcinus magister*) and popular recreational razor clam (*Siliqua patula*) fisheries were disastrous for the fishing communities that rely on them. Here we report on the economic, social, and cultural impacts of the 2015 HAB across 17 fishing communities on the U.S. West Coast using primary interview and survey data. The survey instrument, deployed in the summer of 2017, collected sociodemographic and economic factors hypothesized to confer resilience to HABs, as well as data that quantifies individual impacts. Common themes that emerged from the interview responses indicate that economic hardships extended far beyond fishing-related operations, and permeated through other sectors, particularly the hospitality industry. Some of these impacts persisted long after the bloom had subsided. Long-held traditions surrounding crab and shellfish were disrupted, threatening the cultural identities of the affected communities. Preliminary analysis of the survey data indicates that community members in fishing-related occupations experienced greater impacts compared to those in other occupations. About 90% of respondents with a fishing-related occupation agreed or strongly agreed that the 2015 HAB caused stress in their lives and negatively affected their finances. These results will be used to inform disaster risk-reduction and emergency response strategies to promote practical means of building resilience to HABs.

What you didn't know about west coast commercial fishers

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More than 3,000 vessel owners participate in west coast fisheries each year and they vary widely in terms of what they fish, how much they fish, and why they fish. About a third of west coast fishers participate in more than one fishery, and often in both state- and federally managed fisheries. NMFS and the Pacific Fishery Management Council have typically focused attention on more active fishers in federally managed fisheries, but effectively implementing ecosystem-based fisheries management requires a more holistic understanding of the system of fisheries, fishers, and communities in the California Current Large Marine Ecosystem. To facilitate that understanding, we conducted a survey of commercially active fishers, focusing on reasons and drivers of participation that include non-pecuniary factors such as job satisfaction, identity, and fishing-related social capital. Since many if not most fishers appear to fish part-time, we inquired about how fishing income fits in with other sources of household income. We received over 1,400 responses to the survey (a 50% response rate), and the results describe a highly diverse group of participants with strong attachments and motivations that go beyond income from fishing. They also show widespread dependence on complementary non-fishery sources of income. We present some of the key results from the survey and discuss how this information will be used in a broader effort to develop quantitative models to evaluate how west coast fisheries and communities are linked together through the participation decisions of fishers. The ultimate aim of the larger project is to understand how management policies, environmental variability, and fishery behavior combine to affect outcomes in this complex system.

Upward bound: Rebuilding west coast groundfish stocks

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Many recent stock assessments for west coast groundfish species have shown substantial increases in biomass and rebuilding progress over the past decade. During the 2017 assessment cycle, three rockfish stocks, darkblotched rockfish (*Sebastes crameri*), bocaccio (*S. paucispinis*), and Pacific ocean perch (*S. alutus*) were declared rebuilt ahead of schedule. The rebuilding of these three rockfish stocks continues the successful rebuilding program for west coast groundfish, as eight out of the ten stocks declared overfished since 1999 are now considered rebuilt. In addition, most other assessed groundfish species are well above target levels. We will summarize current status of groundfish as estimated by recent stock assessments and highlight interesting trends across species.

Session 5: Other Fish in the Sea – Research on Non-Salmonid Species

Wednesday, March 28, 11:00 am-12:30 pm

Close-kin methods to estimate census size and effective population size

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Mark-recapture methods are widely used to estimate abundance in natural populations. In a common variation, naturally occurring genetic marks are used to identify individuals, and non-invasive methods are used to obtain samples (e.g., from hair, feathers, scales, feces, etc.). The recently developed close-kin mark-recapture (CKMR) method takes this a step further: close relatives share genetic marks naturally through Mendelian inheritance, so it is not necessary to sample any individual more than once—individuals "mark" their close relatives with shared genes. This talk discusses a collaboration with colleagues from CSIRO in Tasmania, who pioneered the first large-scale application of CKMR, to southern bluefin tuna (Thunnus maccovii). The bluefin study, which genotyped over 13,000 juveniles and adults collected over five years and identified almost 50 parent-offspring pairs, produced an estimate of adult abundance (M) that was both higher (\sim 2×106) and much more precise (CV = 0.17) than has been possible to obtain with standard methods. This result has attracted a great deal of attention around the world and interest in applying the method to other species. Current efforts focus on expanding the genetic assays to detect the many thousands of DNA markers that occur in all species, and this will provide enough power to consider different classes of relationship (especially half-siblings). However, this also complicates analyses, because a widely used genetic method already exists for using the incidence of siblings to estimate effective population size (N). I show how this problem can be resolved with appropriate analytical protocols. I also discuss a variety of biological factors that can affect bias and/or precision of estimates of N and N_e , including age-specific changes in vital rates, overdispersed variance in reproductive success, skip breeding, skewed sex ratio, and non-random sampling. Funding from the NMFS International Science Program helped support this collaboration.

Use of electrophysiological and behavioral techniques in evaluating effect of taurinedeficient diet on olfactory function in sablefish (*Anoplopoma fimbria*)

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The sense of smell is important to fish, connecting them to the environment by relaying chemical information that plays a role in triggering behaviors associated with feeding, predator avoidance, reproduction, and migration. Elecrophysiological techniques make it possible to measure physiological responses to various substances. Amino acids are essential nutrients and are important stimulants of searching and feeding behaviours. Sensitivity to different types of amino acids has been shown in fish and varies among species. Using the electro-olfactogram (EOG) and the electroencephalogram (EEG), it is possible to measure the neurological responses to these compounds at the receptor sites in the olfactory bulb. Development of alternative, terrestrial plant-based feeds raises issues with the proper balance of essential amino acids. Taurine functions very similarly to an amino acid and is absent in plant proteins. This talk presents an example of how electrophysiological techniques can be used to study a diet lacking in taurine. In this pilot experiment, sablefish were fed diets with either 0 or 1.5% taurine, or a reference diet. Fish receiving the diet with 0 taurine tended to have EEG responses that were shorter in duration than diets with taurine. Low dietary levels of taurine have been shown to be associated with reduced growth when compared to sablefish receiving optimal levels of dietary taurine. Feeding response behaviors are triggered by olfactory input. To test whether response to an olfactory feed stimulus is affected by levels of dietary taurine, fish were fed diets containing either 0 or 1% taurine. Response to a food odor (squid extract) was assessed using a behavioral test chamber. Fish receiving the reduced-taurine diet responded less than those receiving optimal dietary taurine. Taurine plays a part in a variety of physiological functions. Altered olfaction responses from taurine deficiency may be an indicator of further systemic problems.

Use of remote-sensing data to understand and forecast catch variability of the Indian oil sardine (*Sardinella longiceps*)

Eli Holmes*, Nimit Kumar, Sourav Maity, Smitha B. R., Sherine Cubelio, Cara Wilson, Narayanane Saravanane, and Nagaraja Kumar

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The Indian oil sardine is one of the most important commercial fishes on the southwest coast of India and represents ~40% of the total commercial catch in the southeast Arabian Sea. Landings of the oil sardine are highly variable, and understanding the environmental drivers of this variability would help support the fishery and its management. Productivity during the juvenile period is assumed to be an important driver, as it is for many small forage fish. In the southeast Arabian Sea, productivity is strongly influenced by seasonal coastal upwelling associated with the summer monsoon (June-September). However, other drivers may also be at play. Precipitation during the monsoon triggers spawning and brings sardines into coastal areas where they are exposed to fishing. We used generalized additive models to test hypotheses concerning the environmental drivers of variability in oil sardine catch. We developed a suite of satellite-derived covariates for the putative drivers; a coastal upwelling intensity index based on sea surface temperature (SST), sea surface chlorophyll. sea surface height, and ocean precipitation. We found no support for precipitation as an explanatory variable. The strongest predictor of the peak catch was the upwelling strength during January–March, 4–6 months prior. This is a period when the young of the year and age-1 fish are found in large shoals in the coastal region. We also found significant correlation between average SST during the early post-spawning period (July-December) and catch in the next two seasons. The effect of SST was a step-response with a threshold SST, and similar to the SST response seen for Pacific sardine catch. The best models had an adjusted R² of 0.73 with SST, upwelling index, and prior-year catch as covariates. This compared to an adjusted R² of 0.27 for models with only prior-year catch as a covariate.

Genetic population structure of lingcod (*Ophiodon elongatus*)

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Lingcod are a high trophic level, demersal predator that range from Kodiak Island, AK, to Punta San Carlos, Baja California, and represent an important commercial and recreational west coast fishery. In the late 1990s, lingcod spawning biomass dropped below 20% of its unfished levels and was designated overfished in 1999. However, the stock quickly rebuilt to the coastwide target level by 2003 following strong recruitment in 1999 and 2000, and was officially declared rebuilt in 2005. Lingcod populations in the southern extent of their range (i.e., Southern California), however, have shown slower stock recovery than northern populations, which could be due to relatively low connectivity between regions. In order to effectively manage this fishery into the future, we are evaluating the extent to which demographic rates and life history traits vary spatially, and whether there is a genetic basis to this variation. Previous population genetic analyses—using allozymes, mitochondrial DNA, and microsatellite markers—investigated structure but yielded equivocal results. Here, using thousands of genome-wide RADseq markers, we present preliminary findings that suggest a strong break in population genetic structure for lingcod in Central California.

A role for critical lipids in the impacts of oil spills on population recruitment in high-latitude fish species

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Omega-3 lipids like docosahexaenoic acid (DHA) are critical fuel for growth of marine fish larvae at high latitudes. Moreover, recruitment in these populations depends on maximizing growth and lipid-energy storage before the first winter after hatch. Exposure to crude oil during embryogenesis reduces subsequent growth and survival in juvenile fish by an unknown mechanism, although the developing heart is the primary target of crude oil toxicity in embryos. Combining hypothesis-driven and shotgun approaches (i.e., high-throughput RNA sequencing), we now mechanistically link early developmental cardiotoxicity to lipid metabolism and growth in key commercial and forage fish species of the North Atlantic, North Pacific, and Arctic: Atlantic haddock (Melanogrammus aeglefinus), Pacific herring (Clupea pallasii), and Arctic cod (Boreogadus saida). Transcriptome sequencing in haddock first suggested disruption of lipid metabolism by embryonic exposure. Experiments described here link these early effects to later growth and lipid composition in Arctic cod and Pacific herring. Embryos were exposed to realistically low levels of Alaskan crude oil, then hatched and reared in clean water. Cardiac phenotypes were determined at hatch, while lipid composition and biometrics were determined at several points representing each stage (embryo, larva, juvenile). Minimal exposure for both species led to measurable cardiac defects at hatch in otherwise normal-appearing larvae. However, once feeding exogenously, these fish showed derangements in lipid composition and growth impairment. Arctic cod showed dose-dependent increases in triacylglycerols (TAGs) and free fatty acids (FFAs) in larval stages, but reduced TAG levels after metamorphosis. Analysis of specific FFA classes in herring larvae showed a significant reduction of DHA and other saturated FFAs. These impacts on both storage and fuel lipids (TAGs and saturated FFAs) suggest a model in which embryonic oil exposure leads to an irreversible lipid-bioenergetic deficit as a mechanism underlying poor growth and, consequently, reduced overwinter survival and recruitment.

Oceanographic drivers of sablefish recruitment in the California Current

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Oceanographic processes and ecological interactions can strongly influence recruitment success in marine fishes. Here, we develop an environmental index of sablefish (*Anoplopoma fimbria*) recruitment with the goal of elucidating recruitment-environment relationships and informing stock assessment. We start with a conceptual life history model for sablefish on the U.S. West Coast to generate stage- and spatiotemporally specific hypotheses regarding the oceanographic and biological variables likely influencing sablefish recruitment. Our model includes seven stages, from prespawn female condition through benthic recruitment (age-0 fish) for the northern portion of the U.S. West Coast sablefish stock (lat 40–50°N). We then fit linear models and use model comparison to select predictors. We use residuals from the stock-recruitment relationship in the 2015 sablefish assessment as the dependent variable (thus removing the effect of spawning stock biomass). Predictor variables were drawn primarily from ROMS model outputs for the California Current Ecosystem. We also include indices of prey and predator abundance and freshwater input. Five variables explained 57% of the variation in recruitment not accounted for by the stock-recruitment relationship in the sablefish assessment. Recruitment deviations were positively correlated with: 1) colder conditions during the spawner preconditioning period, 2) warmer water temperatures during the egg stage, 3) stronger cross-shelf transport to nearshore nursery habitats during the egg stage, 4) stronger long-shore transport to the north during the yolk-sack stage, and 5) cold surface water temperatures during the larval stage. These results suggest that multiple mechanisms likely affect sablefish recruitment at different points in their life history.

Session 6: Abiotic Habitat Stressors Wednesday, March 28, 1:30–2:45 pm

Blobbed! Using salmon growth to diagnose disruption in the northern California Current Ecosystem, 2000–17

Brian Beckman*, Cheryl Morgan, Larissa Rohrbach, and Meredith Journey

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Ecosystems of the northeast Pacific Ocean have characteristically varied over decadal scales, with variation in the Pacific Decadal Oscillation (PDO). The PDO is an index of spatial temperature patterns, with positive PDOs relating to warm water temperatures along the Oregon/Washington coasts and negative PDOs relating to cool water temperatures. In turn, this variation in temperature has been related to ecosystem productivity, with negative PDOs related to higher productivity in the Northern California Current (NCC) Ecosystem. The "Blob" was a large area of anomalously warm surface water that formed in the NE Pacific over the winter of 2013-14. The formation of this warm water pool was related to a persistent ridge of high pressure off the west coast that reduced atmospheric mixing and thus cooling of waters in the Gulf of Alaska. The ecosystem effects of the Blob are still being documented and analyzed. We indexed growth of juvenile coho salmon (Oncorhynchus kisutch) in the NCC by measuring levels of the hormone insulin-like growth factor 1 (IGF1). IGF1 is a hormone that circulates in the blood and directly stimulates growth. On an interannual scale, we found that growth was well correlated to an index of salmon food abundance, suggesting food availability is a major driver for growth variation. We also documented a long-term negative correlation between growth and the PDO, with higher growth during periods of negative PDO. Subsequently, the Blob disrupted this relationship and we recorded the highest IGF1 level in the time series during a period of positive PDO and warm ocean temperatures. Overall, the occurrence of the Blob and the biological response to it represent a stress test of our ability to discern rapid regional climate change and measure ecological response. This talk highlights the utility of having long-term ecological baselines to demarcate biological effects of climate change.

Investigating the effects of early-rearing environment on DNA methylation programming in hatchery-reared steelhead (*Oncorhynchus mykiss*)

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Relative reproductive success studies have documented substantial fitness loss for wild steelhead after a single generation of rearing in the hatchery, but the relative contribution of genetic selection and/or environmentally induced heritable epigenetic changes passed through the germline are relatively unknown. The aim of this work is to examine the effects of an early-rearing environment on epigenetic programming in steelhead. In an initial study, we described epigenetic variation in hatchery and natural-origin (wild) steelhead from the Methow River. We identified significant differences in DNA methylation between hatchery and natural-origin fish, but also observed a high degree of epigenetic variation among individuals, necessitating studies on how epigenetic and genetic variation interplay to promote such differences, and how much epigenetic variation is inherited. To limit the potential confounding effects of genetic variation, a second study using controlled genetic backgrounds and simulated "hatchery" and "natural" environments was performed. Steelhead embryos from 20 families were split across hatchery and natural treatments. After eight months in the treatment environments, fish were tagged and raised to maturity in a common environment. Sperm samples collected from 60 fish were analyzed using RRBS. Hierarchical clustering of genome-wide methylation patterns shows strong clustering within family regardless of rearing environment. These results highlight a major challenge in DNA methylation studies in natural populations, where population structure and kinship among samples is typically not known, let alone controlled for. Our findings emphasize the importance of understanding the effects of kinship among studied individuals in order to properly analyze and interpret DNA methylation data.

Elevated CO₂ disrupts salmon olfactory function and behavior

Chase Williams, Evan Gallagher, Paul McElhany, Shallin Busch, Michael Maher, Theo Bammler, James MacDonald, and Andrew Dittman*

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Increasing levels of atmospheric CO₂ are significantly altering the seawater carbonate chemistry and pH of the world's oceans. The resulting acidification of the ocean (OA) can have harmful effects on marine invertebrates and fish species worldwide. In marine fish, elevated levels of CO₂ have been shown to disrupt numerous neuronal sensory systems. This is a particular concern for species like Pacific salmon (*Oncorhynchus* spp.), that rely on the olfactory system for almost all aspects of their life history including predator avoidance, prey detection, identifying conspecifics, and homing back to their natal streams. In this study, we investigated the effects of elevated CO_o on salmon olfactory-mediated behaviors, as well as changes in neural signaling and gene expression within the peripheral and central olfactory system. Juvenile coho salmon (O. kisutch) were exposed to three different levels of CO_o for two weeks. These included a control reflecting current CO₂ levels in Puget Sound (pH 7.8) and two elevated levels of CO₂ (pH of 7.5 and 7.2) reflecting predicted future levels of CO₂. Our study found that coho exposed to increasing levels of CO₂ showed a reduction in avoidance behavior in response to an alarm odor compared to the controls. Furthermore, exposure to the high level of CO₂ did not alter odorant-induced signaling in the olfactory epithelium, but did induce significant changes in signaling within the olfactory bulbs, RNA-seg analysis revealed significant changes in expression of genes involved in neuronal signaling and signal modulation within the olfactory bulbs from coho exposed to the high CO₂ level compared to control coho. Our results indicate that coho salmon exposed to elevated CO_o can experience significant behavioral impairments that are potentially driven by alteration in higher-order neural signal processing within the olfactory bulbs.

Low regional mountain snowpack and warm air reduce seasonal residence of juvenile anadromous fish in mainstem and estuary habitats

Stuart Munsch*, Correigh Greene, Rachel Johnson, William Satterthwaite, Hiroo Imaki, and Patricia Brandes

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Migration often places juvenile fish in environments that promote development and survival. Anadromy is a common migratory life history whereby adults inhabit marine waters but juveniles rear, typically during springtime, in rivers and estuaries. These ecosystems act as nurseries until the fish emigrate, often as seasonal temperatures rise and watersheds dry. However, mountain snowmelt and cold air may keep waters cool and flowing longer into spring, prolonging the window that juveniles can inhabit watersheds. We quantified the influence of mountain snowpack and air temperature on water conditions and the springtime watershed residence of an anadromous fish to understand how dynamic environmental conditions constrain seasonal windows in which juveniles can use nursery habitats. When springtime snowpack was high and air was cold, cool, flowing waters persisted into the spring, fish resided longer into the spring, and the maximum size of fish emigrating to sea was larger. Thus, snow and air temperature appeared to determine the close of an annual window for juveniles to rear in the watershed. Given widespread expected decreases in snowpack and increases in air temperature, springtime rearing in some species may be compromised, reducing the quality of their watershed habitats and truncating life histories that rear late in spring.

Using DTAGs to understand sound use, behavior, and vessel and associated noise effects in Southern Resident killer whales

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Prey availability and disturbance from vessels and noise are identified threats to the recovery of endangered Southern Resident killer whales (Orcinus orca). Vessels and noise can mask echolocation signals used to capture fish prev and/or disrupt foraging behavior, with implications for energy acquisition in a population that is likely prey-limited. In this investigation, we utilized suction cup-attached digital acoustic recording tags (DTAGs), consisting of hydrophones and movement sensors, to measure received noise levels, understand killer whales' use of sound, and determine effects of vessels and noise on subsurface behavior. During the 28 tag deployments on individually identified Southern Resident killer whales, we collected detailed georeferenced vessel data concurrently as conditions allowed, along with opportunistic observations of predation to validate feeding. Received noise levels (dB re 1uPa) were significantly different across years. Of the vessel factors considered, both vessel count and speed, but not distance, explained differences in noise levels. We noted that sonar signals emitted by vessels in the 50 kHz range were commonly received by the DTAGs and overlap with the echolocation frequencies that the whales use to hunt their fish prey. Additionally, the analysis of the acoustic data from the tags allows us to differentiate different phases of foraging (searching, pursuing, and capturing prey), including the detection of sounds of crunching and tearing to confirm fish kills. In summary, animal-borne DTAGs provide powerful data to better understand subsurface killer whale behavior, including detailed foraging behavior at the individual level, in order to investigate vessel and noise effects. This analysis, along with related analyses and a planned comparative investigation with Northern Residents, inform Southern Resident killer whale conservation and management actions.

Session 7: Modeling and Risk Assessment Wednesday, March 28, 3:15–4:09 pm

How do gear, participation, and dealer selection decisions relate to value? A price analysis of the U.S. West Coast sablefish

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Sablefish (*Anoplopoma fimbria*) is a commercially important species with catch allocated across multiple sectors and gear types on the U.S. West Coast. Additionally, a flexibility provision in the West Coast Groundfish Trawl Catch Shares Program sanctions those with trawl permits to target sablefish with fixed gear, such as longlines or pots. This allows the total effort by gear type to be partially determined by market forces, as individual fishers seek to maximize their profit. With interquartile ranges in price of \$1.44 per round pound for trawl-caught sablefish, \$1.72 for fixed gear-caught sablefish, and \$1.58 overall, it is important to better understand which characteristics best explain the variation in ex-vessel prices, as well as the magnitude of these differences, in order to decipher the dynamics that influence participation choices and gear switching. Using a linear mixed model with dealer- and vessel-specific random effects, I explore the influences of gear, grade (size), condition, fishing sector, port group, landing month, and year on price per round pound of sablefish. A second linear mixed model uses weighted average price per trip that incorporates the size composition of trip landings into the explained variable, to look for possible evidence of high-grading in sectors outside of the Catch Shares Program. During this presentation, I will discuss results of these regressions as well as the role of species composition of catch in the context of the Dover sole, thornyhead, and sablefish (DTS) trawl fishery. I will also briefly share preliminary results that utilize the Economic Data Collection Program's information from first receivers and shorebased processors to further explain prices based on more detailed dealer characteristics.

Oceanographic data QA/QC processing

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NWFSC's FRAM Division collects oceanographic data on all its research surveys to include the West Coast Groundfish Bottom Trawl Survey, the Integrated Hake Acoustics Trawl Survey, the Southern California Hook and Line Survey, and a variety of marine habitat surveys using a suite of heterogeneous sensors from a variety of vendors. Recently we began developing a consolidated QA/QC data processing pipeline to prepare these data for subsequent research. This software starts with raw file formats and allows the user to step through a variety of automated and semiautomated steps to visualize and cleanse the data and output it in a standardized format for use in subsequent tools such as R. During this talk, we will discuss the data types processed, the processing steps, and the software architecture as currently implemented. We will also address next development efforts to include public dissemination of the cleansed data.

Co-development of an ecosystem-based risk assessment for California fisheries by scientists, stakeholders, and managers

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Harvesting food from wild populations is risky to communities that rely on those resources and to those responsible for safeguarding conservation goals. Ecosystem approaches to management offer a potential means to balance those risks, but require a method of assessment that is commensurate across multiple objectives and also takes into account the priorities and knowledge of stakeholders. In this study, we capitalized on an opportunity to co-develop an ecological risk assessment (ERA) for California fisheries with scientists, managers, and stakeholders. This ERA was intended to provide a systematic, efficient, and transparent approach to prioritize fisheries for additional management actions and call attention to resourceintensive fisheries. We assessed the relative risk posed to target species, bycatch groups, and habitats from the prosecution of nine state-managed fisheries. We found that risk to bycatch and habitat groups was much more variable than, and not always predictable from, risk to target species. Two commercial fisheries for California halibut (Paralichthys californicus) posed the greatest risk across target species, bycatch groups, and habitats, while in some cases other fisheries produced the greatest risk for specific ecosystem components. The ERA tool presented here allows for an integrated perspective on risk across the ecosystem, as well as evaluation of cumulative risks across fisheries to non-target species and habitats. Most importantly, the participatory process used to generate these results illustrates a clear pathway to increasing stakeholders' trust in the assessment and the potential for application in management. We suggest that adopting similar processes in other management contexts and jurisdictions will advance progress toward ecosystem-based management of natural resources that simultaneously satisfies conservation and relationship-building objectives.

Evaluating spatiotemporal reproductive variability in Pacific hake (*Merluccius productus*) using a flexible asymptotic model to estimate functional maturity

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Fisheries managers seek to understand marine species' response to different oceanographic regimes through monitoring and evaluating changes in time and over geographic regions. Many management models used out-of-date maturity studies that were localized and often from unreliable macroscopic maturity estimates. In response to this, NWFSC's FRAM Division instituted a reproductive biology program in 2009. From 2009–16, we histologically assessed 2,544 Pacific hake ovaries collected by the West Coast Groundfish Bottom Trawl Survey, Fisheries Engineering Acoustics and Technology Surveys, and the At-sea Hake Observer Program. These coastwide collections allowed us to explore biogeographic relationships north and south of Pt. Conception, CA (lat 34.44°N) within varying temporal patterns. We used a new flexible spine model to estimate functional maturity by incorporating the fraction of sexually mature skip spawners into the asymptote. Overall coastwide length and age at 50% (L_{50} , A_{50}) maturity was estimated at 33 cm and 2 years. However, L_{50} results north and south of Pt. Conception varied substantially, with corresponding L_{50} estimates of 35 and 26 cm. In addition to the varying spatial relationships, we found temporal trends in their reproductive cycle, including time of spawning, shift in spawning locality, and interannual variability in the rate of skipped spawning. To account for skip spawners into a flexible asymptote.

Sure, South Lake Union has ruined Seattle—but can tech bros teach us anything about building better models for fish?

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Making better predictions of populations or environmental processes in space and time improves our science and makes fisheries more efficient. The majority of models we use in fisheries and ecology are parametric, though non-parametric approaches are rapidly advancing, particularly in other fields. Spatiotemporal approaches to modeling fisheries data have advanced rapidly over the last five years, with many of the advances coming from NWFSC. Major advances include transitioning from strata-based estimation approaches to Gaussian process models, which incorporate spatial covariance between locations. These newer methods have been shown to increase the precision of density estimates and better capture distribution shifts over time. In this talk, I discuss the pros and cons of parametric and non-parametric approaches, and highlight two examples of comparisons between Gaussian process models and similar approaches using machine learning tools (random forests, neural networks). First, we apply these methods to fisheries bycatch data to evaluate the relative performance of different methods for estimates of species caught as bycatch in the west coast groundfish trawl fishery. Across species, we find some advantages of random forests, but with a cost of increased biases. As a second example, we develop a simulation comparison for the NWFSC trawl survey. Finally, I discuss the implications of these methods for developing more precise estimates of abundance and fleet-wide bycatch.

Poster Abstracts

Poster Presentations Tuesday, March 27, 3:32-5:30 pm

Regulation of muscle growth in sablefish (Anoplopoma fimbria) during grow out

Lisa Armbruster*, Adam Luckenbach, William Fairgrieve, Madison Powell, Ronald Johnson, Walton Dickhoff, and Gordon Murdoch

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Skeletal muscle accounts for the bulk of body mass in finfish species selected for aquaculture. This fact highlights the importance of understanding muscle tissue development to enhance overall growth. Hatchery and grow-out protocols are being developed for sablefish (*Anoplopoma fimbria*), an emerging west coast aquaculture industry. Producers stand to benefit from knowledge of how the "growth environment" (e.g., temperature, nutrition, pedigree) impacts muscle tissue development, growth potential, and product quality. The research presented here is part of a larger study investigating development of red and white muscle using 11 molecular markers of muscle growth and metabolism. This work begins to decipher the transcriptional regulation of muscle development in sablefish and serves as a baseline to which future comparisons can be made to expedite decisions for optimal production by the aquaculture industry. Species-specific qRT-PCR assays were developed for highly conserved target genes with known critical functions in vertebrate muscle development. These tools were employed to measure mRNA levels in muscle from a cohort of cultured sablefish at four time points, spanning 16 months of grow out. It is important to evaluate red muscle-specific growth because it represents a localized microniche (e.g., blood supply, maturity, metabolism) where satellite cell recruitment and myogenesis differ from those observed in white muscle. Differential regulation of the target genes (e.g., MyoD1, MyoD2, Myogenin, MRF4) during the growth cycle is suggestive of important and conserved roles in sablefish muscle development. These molecular tools will be further validated and used to determine what growth environment maximizes sablefish growth performance.

Assessing the impacts of toxic mixtures over a broad geographic scale: Challenges and first steps

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Assessing the risks posed by chemical mixtures is a complex process. Ideally, details are available on exposure (e.g., which chemicals and what concentrations) and effects (e.g., mechanisms of action and toxicity data). Even for a single location and time, such as a lab or field site, this can be challenging. Unfortunately, risk assessments often need to cover much larger scales, such as an entire watershed or a wide-ranging species. This increase in scale substantially increases the risk assessment complexity. Thousands of chemicals in use lead to potential environmental mixture exposures, including pesticide runoff and municipal wastewater discharges. At the landscape scale, the nature of chemical mixtures will vary across space and time. At this increased complexity, available monitoring data are inadequate for describing realistic exposure scenarios and effects on aquatic species. Therefore, creative solutions are required to utilize sources of data that are available to identify where and when risk is the greatest. Sources of data are available for beginning to develop a less-detailed, but still useful, landscape-scale risk assessment for mixtures. These include data on potential use (e.g., crop locations and pesticide labels) or release (e.g., mapping of NPDES permits) sites. For example, the use of crop designations to represent where pesticide use is allowed can be a surrogate of actual use, to establish where the greatest potential for exposure occurs. This landscape-scale risk assessment for mixtures can establish priority watersheds for monitoring and further study. Similarly, aquatic species exposure to complex mixtures discharged in wastewater can be related to urban land uses and permit distributions. The goal is to develop a process to prioritize the relative risks and identify important data needs necessary for more detailed mixture analyses in the context of a landscape-scale risk assessment.

Where are the walleye? Tracking non-native walleye in the Lake Washington watershed using environmental DNA

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Walleye (Sander vitreus), a non-native predator of ESA-listed salmon, were first discovered in spawning condition in the Lake Washington watershed in 2015. Once an invader is detected, early intervention is critical to prevent establishment. Although walleye have been incidentally caught since 2005, efforts to study and manage walleye have thus far been hampered by the inability to reliably locate walleve, especially outside of their early-spring spawning season, in 2016, we began piloting eDNA sampling for walleye. eDNA sampling may detect rare organisms that traditional survey methods might miss, thus providing a lower cost per effort and potentially more successful method to gather information on walleye spatiotemporal habitat use. Importantly, eDNA sampling also poses no threat to salmonids. We compared the efficacy of eDNA versus traditional field-based methods for determining walleve presence by: 1) coupling known walleve presence in gillnets with eDNA sampling as a proof of concept, 2) eDNA sampling when walleye were not observed in gillnets, and 3) comparing detection rates in surface and subsurface water samples when walleve were not visually observed. When water samples were collected with a walleye present in the net (n = 9), we detected walleye eDNA 100% of the time. Some sample replicates with a walleye present were negative, giving us confidence that our methods are not leading to false positives, while also demonstrating the patchiness of eDNA in a large lentic system. We collected water samples at 27 locations, some repeated, when gillnets were in the water but walleye were not caught in the net. Of these, 4/27 locations were positive for walleve DNA, never more than one site on a sampling day. Further, positives were always from a sample taken at 3 m depth but never found in the 1 m depth sample at the same site. This suggests that eDNA sampling does a better job of identifying walleye presence/absence than does traditional net sampling.

Relating groundfish diversity and biomass to structure-forming invertebrates in the northeastern Pacific Ocean: An exploration of catch data from a fishery-independent trawl survey

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We investigated the associations between structure-forming invertebrates (SFIs: corals, sea pens, and sponges) and demersal fish using bottom trawl survey data from the Northwest Fisheries Science Center's West Coast Groundfish Bottom Trawl Survey (2003—15). General linear models (GLMs) showed that average species richness was slightly lower, and finfish biomass slightly higher, in hauls with no SFIs. Generalized additive models (GAMs) indicated non-linear relationships between species richness and sponge density. Slightly higher finfish biomass occurred in hauls with few or no sea pens or sponges. We used multivariate analyses to examine relationships between fish community structure, SFI densities, and environmental parameters (depth, latitude, and bottom temperature). No strong correlations occurred between community structure and SFI densities, but bottom temperature and depth were the primary drivers of community composition. However, indicator species analysis, based on three SFI levels (high, low, and none), showed various species-specific associations. Depending on species, flatfishes exhibited relationships with high and low densities of corals and sea pens or the absence of sponges. Thornyheads and some rockfishes (*Sebastes* spp.) were associated with high sponge densities but low or zero coral and sea pen densities. Sablefish (*Anoplopoma fimbria*) exhibited opposite trends. These results provide information about broad-scale associations between SFIs and demersal fish that may be useful for developing studies specifically focused on the function of SFIs as essential fish habitat and the role they may play in the life histories of groundfishes.

Fine-scale benthic habitat classification using a towed video camera-sled

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The Northwest Fisheries Science Center's Southern California Shelf Rockfish Hook and Line Survey samples hard-bottom habitats within the Southern California Bight via rod-and-reel gear to provide management information for multiple demersal rockfishes (*Sebastes* spp.). The survey, initiated in 2004, consists of 201 fixed stations sampled annually from Pt. Arguello (lat 34.6°N) to the U.S.—Mexico border (lat 32.1°N) at depths of 37–229 m. We analyzed 8,260 benthic habitat observations collected during 90 dives representing 70 unique sites via deployment of a towed video camera-sled. Benthic habitat observations were categorized both by major strata (primary: ≥50% of the field of view; secondary: ≥20% of the next most abundant habitat; and all other habitats in the field of view), and by eight substratum categories: mud, sand, pebble, cobble, boulder, continuous flat rock, diagonal rock ridge, and vertical rock/pinnacle top. When compared with existing NOAA essential fish habitat (EFH) maps, we found significantly different habitat classification values, especially of hard substrates. Available EFH maps contain varying degrees of resolution, or use algorithms to predict benthic habitat composition, which likely reduces classification accuracy. Our analysis of camera-sled tows showed 47% hard-bottom habitats and 53% soft-bottom habitats. EFH designations in the same areas as our camera-sled tows comprised 27% hard-bottom substrates and 73% soft-bottom substrates, with both values differing significantly from the corresponding camera-sled observation data. Our findings indicate that hard-bottom habitat features, especially smaller reefs, may not adequately be resolved within some available habitat maps.

Extreme hypoxia impacts catches on the 2017 West Coast Groundfish Bottom Trawl Survey

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Seasonal hypoxia has been observed in near-bottom waters of the Oregon continental shelf since 2002. Potentially linked to shifts in climate and upwelling, the severity of these hypoxic events has varied considerably over time. In 2017, the West Coast Groundfish Bottom Trawl Survey encountered severe hypoxia in shelf tows with depths ranging from 62 to 160 m off the coasts of Oregon and Washington. Near-bottom dissolved oxygen levels as low as 0.10 mL L⁻¹ correlated strongly with reductions in groundfish catches. Large quantities of decomposing Dungeness crabs encountered in other areas suggested that these hypoxic conditions may have been widespread and resulted in local die-offs of benthic invertebrates. We examine the extent and intensity of near-bottom hypoxia observed in 2017, analyze catches of groundfish and invertebrates from oxygen-poor locations, and explore environmental factors that may have contributed to the severity of this phenomenon in 2017.

Spatial growth variability in marine fish: Example from northeast Pacific groundfish

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Life history parameters of marine fishes vary in space and time, often in response to multiple factors. Understanding this variability is vital to ensuring the sustainability of marine resources and ecosystem services provided by the ocean. We examined spatial variability in growth for a number of groundfish species in the northeast Pacific Ocean to identify shared spatial patterns and hypothesize about common mechanisms behind them. Growth parameters were estimated in different areas over the latitudinal range of the species and multiple hypotheses were tested as to whether growth parameters differ in all the areas, at specific area breaks, or exhibit a latitudinal cline. Clear differences in spatial growth variability emerged among the species examined. Shelf species exhibited the highest growth rate between Cape Blanco and Cape Mendocino, which may in part be attributed to area-specific upwelling patterns in the California Current Ecosystem, when nutrient-rich deep water is brought to the surface southward of Cape Blanco and uniquely distributed throughout this area, providing favorable conditions for primary productivity. Slope species showed a cline in asymptotic size (L__), with L__ increasing from south to north. This cline, previously attributed to fishery removals, also fits a specific case of the widely described Bergmann's rule, and we explore specific potential ecological mechanisms behind this relationship.

Variation in minijack rates among interior Columbia River basin Chinook salmon hatchery stocks: A common garden experiment

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Age of male maturation in spring Chinook salmon (*Oncorhynchus tshawytscha*) can occur at age-1 (microjack), age-2 (minijack), age-3 (jack), or age-4-6 (typical adult). In 2014, we conducted a comprehensive survey of precocious male maturation (minijack rates) of yearling Chinook salmon at various Columbia River basin hatchery programs and found minijack rates ranging from 8-71% of males released. Maturation is considered a threshold trait, where the physiological decision to mature at any age class is dependent on size or energetic status of the individual fish at specific times of the vear. Both genetics and rearing environment can influence this decision. In this investigation, we carried out a common garden experiment to look for stock-level differences in size thresholds for maturation as minijacks. We collected eyed embryos from ten hatchery stocks throughout the Columbia and Snake River basins (10 families equally represented per stock) and transferred them back to the NWFSC research hatchery. At the stock level, reaction norms (relationship between phenotypic expression and an environmentally influenced variable, such as size) for each population can be compared if the environment is controlled across each population. To control for environmental effects on early male maturation, fish from all hatchery programs were reared under identical densities, photoperiod, water temperature, and feed regimes. This resulted in nearly identical growth rates and mean sizes across groups. The resulting minijack rates from this experiment ranged from 4–44%, thus exhibiting different size thresholds for early male maturation. These differences in size thresholds between populations have implications for determining growth regimes and size-at-release goals for each hatchery program. This research highlights the fact that stock-specific trade-offs exist between improving smolt survival by growing larger fish and altering the age demographics of populations by increasing the incidence of precocious male maturation.

Triploidy induction as a potential method for reproductive sterilization of sablefish (*Anoplopoma fimbria*)

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Approaches for reproductive sterilization are needed for the marine aquaculture industry to mitigate public concern associated with escapement of farmed fish and potential genetic contamination of wild stocks. This need pertains to all marine species grown in ocean net-pen systems and is a critical goal to increase sustainability of U.S. marine aquaculture. One such approach is triploidization, a technique that has been widely used for sterilization of salmonid fishes (e.g., rainbow trout) but not well explored in marine finfishes. Triploidy is achieved by applying a "shock" (thermal, pressure, or chemical) at an appropriate time following fertilization to disrupt completion of meiosis and induce retention of an extra set of maternal chromosomes by the embryo. This study focused on two different approaches, hydrostatic pressure or thermal shock, to generate triploid sablefish. The efficacy of each approach was evaluated under varying conditions (timing of the shock, duration, and intensity) to determine optimal protocols for triploidy induction. Survival of triploid sablefish relative to (diploid) controls was evaluated by first assessing the percentage of embryos with normal cell symmetry and then the percentage of hatched larvae. Methods were established to determine ploidy in triploid versus diploid sablefish using flow cytometry and microscopy at different stages of development (embryo, larvae, and juvenile blood), allowing for ploidy determination as early as 10 days post-fertilization. This study resulted in successful protocols for generating triploid sablefish with either thermal or pressure shock. Early results of histology indicate some inhibition of reproductive development in triploid sablefish; however, triploidy is thought to disrupt processes associated with meiosis, so effects may become more apparent during later stages of development. We plan to monitor the diploid and triploid groups long-term to evaluate both their reproductive development and performance in aquaculture.

The use of electronic monitoring for catcher vessel discards in the at-sea Pacific hake fishery

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Electronic monitoring (EM) is used to account for most discarded catch in the mothership catcher vessel fleet in the at-sea Pacific hake (*Merluccius productus*) fishery. From 2011–15, the catcher vessel (CV) carried an observer on board to record discard estimates. Most vessels switched to using EM as it became available in 2015. Discard estimates from 2011 to 2015 were reported by the CV observer to the mothership (MS) observer. Currently, the CV captain in-season reports an estimate of discard to the MS observer. At the conclusion of the trip, the EM video is sent to be reviewed. The reviewer watches the video and records a discard estimate. Adjustments are made between the two based on established rules for a finalized accounting of total discards. The catcher vessel fleet is a unique platform for EM. No hands-on biological data are collected. The video reviewer can view a single discard event from different camera angles, slower speeds, and multiple times, to get the most accurate discard estimate possible. EM discards should be the most accurate, comprehensive, and safest method to account for discards in the at-sea Pacific hake fishery.

Effects of high temperature on early reproductive development of sablefish (*Anoplopoma fimbria*)

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Aquaculture supplies over half of all seafood produced for human consumption. However, production processes are raising environmental concerns, and escapement of farmed fish is a prominent issue. A viable solution is to produce reproductively sterile fish so escapees cannot genetically contaminate wild populations. For this study, we examine high temperature treatment as a method for achieving sterility, since it is shown to induce germ cell loss in some female fishes. Monosex female sablefish larvae (~90 days post-fertilization) were randomly divided into three groups and exposed to different temperatures, control (15°C), moderate (20°C), or high (22°C), for ~4 months. During this time, larvae were periodically sampled for assessing gonadal development. A portion of the gonads was fixed for paraffin histology and a portion preserved for later gene expression analyses. After the treatment period, remaining fish were tagged and transferred to ambient temperatures for one year to determine whether temperature effects were maintained post-treatment. We found that exposure to higher temperatures induced severe impairment of early ovarian development. Sablefish at moderate and high temperatures had significantly lower oocyte counts and less developed oocytes relative to controls. However, after one year at ambient temperatures, impaired gonads were no longer observed and most high temperature-treated fish had ovaries similar to those of controls. We also observed two sex-reversed females (female genotype but male phenotype), referred to as neomales, from the high-temperature group, which opens the possibility of using high temperature for future neomale broodstock production. Neomale broodstock are a key component for monosex sablefish production, and being able to generate them via high temperature may represent an improvement upon current methodology. Based on these results, we conclude that high temperature is likely not an effective method for inducing reproductive sterility, but may be a preferable method of neomale production in sablefish.

Toxicity of pharmaceutical drugs to embryonic zebrafish

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Pharmaceuticals and personal care products (PPCPs) are aquatic contaminants that have been detected in surface waters globally. However, their aquatic toxicity, especially in complex mixtures, has not been thoroughly characterized. In order to better understand PPCP toxicity, zebrafish (*Danio rerio*) embryos (<48 hpf) were exposed to two cardiac-specific medications, triamterene (a diuretic used to control hypertension) and gemfibrozil (a fibrate used to regulate cholesterol) as both single chemicals and binary mixtures. Morphometric analysis revealed that gemfibrozil elicited a dose-dependent decrease in eye area and embryo length, as well as a dose-dependent increase in yolk sac area and cardiac abnormalities. Triamterene did not induce significant dose-dependent trends. Results from mixture trials were compared to toxicity predicted by a response addition model. Additive toxic effects were observed in all endpoints, with potential synergism evident at higher concentrations when yolk sac size was used as the measure of toxic effect. Additionally, thin layer chromatography coupled with flame ionization was used to quantify lipid levels in exposed embryos. Results showed elevated lipid levels in gemfibrozil-exposed embryos, suggesting the drug blocks lipid metabolism in developing zebrafish embryos. This metabolic pathway may be altered by the presence of other drugs, since the mixture of triamterene and gemfibrozil together did not alter lipid levels compared to control fish. These trends indicate that PPCPs may be important environmental stressors to fish early-life stages, especially drugs that affect lipid metabolism and subsequent growth and development.

Spatial and temporal variability of nearshore forage fish in the Strait of Juan de Fuca

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The Salish Sea supports local populations of many fish species, including migrating juvenile salmon and rearing and spawning forage fish. Population dynamics of ecologically important forage fish are poorly understood in this region. Over nine years of monthly beach seine sampling (April-September) at 24 sites along 70 km of coastline in the Strait of Juan de Fuca, we have observed high variability in fish catch across years, sites, and seasons, Annual catches ranged from 23,093 to 92,677 individual fish divided among 45 to 55 species. Forage fish were represented by nine species and were numerically the dominant group, accounting for 87.8% of the catch from all sampling areas combined. Influence of individual species varied, yet drove the fish assemblage. We explored effects of temporal and spatial variability on forage fish occurrence, abundance, and community composition using descriptive statistics and a Bayesian hierarchical modeling framework. Additionally, the removal of two large dams on the adjacent Elwha River, which released stored sediment into our sampling area, provided us an opportunity to examine forage fish response to a localized habitat perturbation. Three forage fish species dominated, thus warranting in-depth investigation: Pacific herring (Clupea pallasii), Pacific sand lance (Ammodytes hexapterus), and surf smelt (Hypomesus pretiosus). These showed species-specific variations spatially and temporally. Localized nearshore sediment and vegetation variances drove some of the distribution differences between these species. Furthermore, the abundance of other forage fish species increased when these populations were depressed. Spatially, individual species may avoid regions of high perturbation, but dramatic variations in distribution and abundance of the greater forage fish community are temporally driven by larger-scale changes to the region. Future management plans directed at forage fish should take into consideration how this variation in abundance at regional scales and consistent population responses to large-scale environmental drivers may drive anticipated outcomes over time.

Variation in size and catch of demersal fish species within the Southern California Bight in relation to the Cowcod Conservation Areas (2014–16)

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Since 2001, fishing has been prohibited at depths greater than 36 m in two large (10,878 km² and 260 km²) Southern California Bight marine reserves known as the Cowcod Conservation Areas (CCAs). The Pacific Fishery Management Council established the CCAs in response to declining abundance of west coast rockfishes, particularly overfished cowcod (*Sebastes levis*). We investigated variations in catch rate, size, length frequency, and percent of positive sites for 11 abundant groundfish species¹ and the vermilion/sunset complex (*S. miniatus/crocotulus*) inside and outside the CCAs using data from the Southern California Hook and Line Survey, an annual fishery-independent survey. From 2014–16, the Hook and Line Survey sampled up to 75 fixed sites within the CCAs and 121 sites outside the restricted areas using rod and reel gear. Generalized linear models that included area, year, depth, and distance from port revealed significantly greater catch (P < 0.05) within the CCAs for eight of 11 species; two species (copper rockfishes and lingcod) and the vermilion/sunset complex were significantly more abundant outside the CCAs. Although more abundant within the CCAs, results for cowcod were not significant (P = 0.13). We also observed significant differences (P < 0.05) in length frequency distribution and mean size for nine species and the vermilion/sunset complex, with larger fish present inside the CCAs. Length frequency and mean size of bank and starry rockfishes were not significantly different by area. The proportion of sites positive for individual species tended to be greater inside the CCAs for nine species, although significant differences occurred only for bank, bocaccio, and starry rockfishes.

†Bank (*S. rufus*), bocaccio (*S. paucispinis*), chilipepper (*S. goodei*), copper (*S. caurinus*), cowcod, greenspotted (*S. chlorostictus*), olive (*S. serranoides*), speckled (*S. ovalis*), squarespot (*S. hopkinsi*), and starry (*S. constellatus*) rockfishes and lingcod (*Ophiodon elongatus*).

Indicators of pesticide exposure in outmigrating juvenile Chinook salmon throughout Puget Sound

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Anthropogenic pollution is a widespread threat to fish health throughout Puget Sound. One specific pollution type is pesticides, chemicals that are currently registered for use on urban, residential, and agricultural lands throughout the Pacific Northwest, Pesticide use across the landscape can impact adjacent water bodies that are also habitat for earlylife stages of Chinook salmon (Oncorhynchus tshawytscha). Accordingly, the Washington Department of Fish and Wildlife (WDFW) conducts routine monitoring of fish health in river systems draining into Puget Sound. Fish collected from one such monitoring effort in the spring of 2016 were analyzed for numerous health parameters, including the activity of the neurological enzyme acetylcholinesterase (AChE). This enzyme is inhibited by certain classes of pesticides, with lower AChE activities suggesting recent pesticide exposure. Analysis of hundreds of fish showed that AChE activities varied among and within river systems, but did not depend on fish size, condition, or origin (i.e., hatchery or natural production). Notably, in the Duwamish River, fish from sites further upriver and adjacent to restored habitats had higher AChE activities (i.e., lower pesticide exposure) than fish caught from more urbanized sites near the river mouth. Likewise, AChE activities of juvenile Chinook caught in nearshore waters were significantly lower near the Stillaguamish River (north Puget Sound) than those near the mouth of the Nisqually River (south Puget Sound). These differences may reflect different patterns of pesticide use on land types within the watersheds. While routine monitoring efforts such as the one described here are not necessarily designed to detect adverse effects following pesticide use, the data can provide useful comparisons of fish health across large geographic scales. Additionally, indicators of fish health collected from routine monitoring can inform specific areas that would benefit from more intensive or focused monitoring.

Overview of research on acute aquatic toxicity from urban stormwater runoff: Collaborations of the Puget Sound Stormwater Science Team

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The Puget Sound Stormwater Science Team is a collaborative research effort by NOAA Fisheries, USFWS, and Washington State University to understand and prevent toxic impacts from urban stormwater runoff. Urban stormwater runoff is acutely toxic to a variety of aquatic animals, including model species such as the waterflea (*Ceriodaphnia dubia*) and the embryolarval zebrafish (*Danio rerio*), as well as non-model species. There are five species of the genus *Oncorhynchus* native to the Pacific Northwest. Coho salmon (*O. kisutch*) is particularly sensitive to urban stormwater runoff. Anadromous adults returning from the ocean to spawn in freshwater show high rates of prespawning mortality in streams that receive runoff from impervious urban surfaces, particularly roads. Experimentally, runoff from roads is sufficient to cause acute mortality in coho adults, juveniles, and hatched embryos. Prior to mortality, a variety of impairments are observed in affected individuals, including an innate immune response, ionoregulatory impairment, and hemoconcentration. Ongoing work strives to understand the cause of death in exposed coho, the extent of impact in regional streams, toxic responses in other members of the aquatic ecosystem, the source and chemical identity of the causative agent(s), and green infrastructure approaches that can mitigate the toxic responses.

Novel fishway entrance modifications to improve passage for native fish

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Healthy riverine ecosystems require provision of passage routes at dams for a broader array of aquatic species than has historically been targeted. To address this need, fishway entrance modifications were made at a large hydropower dam on the Columbia River (Bonneville Dam, rkm 235). These modifications were designed for poor swimmers, featuring a variable-width entrance weir and floor-mounted flow disrupters to reduce water velocity near the bottom without affecting attraction flows in the upper water column (needed for alosids and salmonids). Additionally, a lamprey-specific structure was installed to allow passage from tailrace to forebay elevation (31 m) for Pacific lamprey (*Entosphenus tridentatus*), a species of conservation concern. Lamprey were counted as they exited the structure (2009–16). In addition, passive integrated transponders and radio transmitters were used to assess both lamprey and Chinook salmon (*Oncorhynchus tshawytscha*) entrance success in periods before (1996–2002) and after (2009–14) entrance modifications. Entrance success was also compared for modified and unmodified entrances at Bonneville Dam in each time period. Pacific lamprey passage improved after the modifications, and annual lamprey use of the structure increased from 48 in 2010 to over 3,800 in 2016. Hence, Pacific lamprey exhibited heretofore unknown capacity for elevation gain and appeared to take advantage of flow reductions near the fishway entrance floor. Chinook salmon entrance success was unchanged following the modifications, indicating that retrofits to existing fishways can improve passage for a broader array of species without compromising functionality for historically targeted species.

Emergent fungal infections in Pacific Northwest marine mammals

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Fungal infections in wild marine mammals are uncommon and difficult to document. In the Pacific Northwest, outbreaks of the fungus *Cryptococcus gattii* detected among humans, terrestrial animals, and wild marine mammals had an epidemiological connection, but the number of marine mammals involved was relatively small. The first case of mucormycosis, caused by fungi in the order Mucorales, was diagnosed in 2012 in a stranded harbor porpoise (*Phocoena phocoena*) in WA state. Since 2012, mucormycosis has been confirmed as the cause of mortality in six additional harbor porpoises, one Southern Resident killer whale (*Orcinus orca*), and three harbor seals (*Phoca vitulina*). Analyses of the fungi causing mucormycosis in marine mammals have so far identified *Rhizomucor pusillus* and *Lichtheimia corymbifera*. These species cause the same disease in humans, principally immunocompormised individuals. Among the affected marine mammals, underlying conditions include recent pregnancy/loss of fetus, emaciation, concurrent protozoan infection, and herpesvirus, suggesting that immunocompromised animals may also be susceptible to mucormycosis. In the future, we will continue to identify fungal species causing mucormycosis and to determine the relative distribution of fungal species in marine waters occupied by Pacific Northwest marine mammals. While it is clear that mucormycosis is an emergent disease in marine mammals, understanding its distribution in the marine environment will help predict the likelihood of its persistence as a cause of death.

Interacting effects of translocation and warmer temperatures on the population dynamics of Snake River sockeye salmon

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In 1991, sockeye salmon (*Oncorhynchus nerka*) populations from Idaho's Snake River basin were listed as endangered under the Endangered Species Act. Since then, they have partially recovered due to a captive broodstock and hatchery supplementation program, improvements to natal habitat, and more favorable riverine and ocean conditions. Nevertheless, significant challenges remain. Although record returns were realized for this population to the Columbia River, particularly in 2015, low river flows and high water temperatures substantially impacted upstream survival. Also, in most years, homing impairment of fish barge-transported as juveniles limited upstream migration and survival to spawning. We used detection information from individual fish tagged with passive integrated transponder (PIT) tags to examine the effects of rearing strategy, release protocol, and migration route on survival of both juveniles migrating downstream and adults migrating upstream. Using data from 2009-15, we found that juvenile survival from release sites in natal rearing areas to the first dam they encounter (Lower Granite Dam, LGR) has ranged from 15–71%, with a negative trend since 2011. Those juveniles that were subsequently transported from LGR to below the lowermost dam (Bonneville, BON) had higher, but more variable, survival as returning adults to BON. Upstream survival of adults from BON to LGR was highly variable, ranging from 4–76%. Furthermore, those adults that had been transported downstream as juveniles survived at 35%, compared to 55% for fish that had migrated downstream on their own accord. Taken together, the total survival from LGR back to LGR for transported fish was, on average, 16% lower than fish migrating in-river. Overall, the survival of smolts to adults was extremely low (range = 0.02–0.39%). These results suggest greater scrutiny be given to the interacting effects of juvenile transportation and warmer water temperatures on the population dynamics of this at-risk population of salmon.

Developing a wireless automated data collection platform for sampling groundfish in untrawlable habitats

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Since 2004, NWFSC has annually monitored an array of fixed sampling sites over high-relief habitat using rod-and-reel gear in the Southern California Bight. Pencil-and-paper forms have been used for capturing all back-deck information, such as catch, effort, and biological sampling details. These hard-to-read forms were transcribed into approximately 150,000 unique data fields and manually entered into a relational database during the offseason. In 2017, a portable, rugged, wireless, integrated, and interactive data-collection platform was deployed. The new three-station system is named HookLogger and utilizes Windows tablets, barcode label printers, barcode scanners, and motion-compensated digital scales to input data over TCP/IP using virtual comports. The tablets communicate with a centralized SQLite database located at the primary event-logging galley station. The benefits of this digital data-collection capability include faster, more streamlined field data collection, on-entry data validations, and the elimination of approximately 320 hours of post-season data entry.

A method to measure behavioral response to an olfactory stimulus

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A behavioral analysis method was developed to measure the effectiveness of various feed attractants, as well as to study the difference in olfactory-stimulated behavioral response of fish fed alternative diets either lacking in taurine, or with taurine added. Feeds are being developed that replace traditional fish-derived protein with plant protein. Currently, aquaculture feeds formulated without fish protein do not perform as well as those with fish protein. Some additives, however, may be able to increase food acceptance and growth. A multi-chambered, circular tank is divided into six segments by water currents so that test substances can be contained within one segment, yet fish can move freely between them. Individual fish placed in this system were monitored by recording location in the tank segments before and after introduction of a putative chemoattractant. Presence of the fish in the exposure segment was then compared between pre- and post-exposure recordings. Squid extract was used to test the effectiveness of the experimental design. Without squid extract present, fish tend to swim in circles around the periphery of the tank. With the squid extract present, fish changed behavior and spent more time closer to the center of the tank. The amount of time fish spent in the central sections of the tank was compared with and without odor present. In conclusion, this radial tank design has been validated as an effective platform for behavioral attractant studies. A reference odorant has been identified that is comparable to already published attractant work. Experimental protocols have been established and the groundwork laid for further experiments with a variety of odorants.

How science can help hatchery managers make more informed decisions: The story of the Hood River

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With a goal of releasing 150,000 juvenile spring Chinook salmon (*Oncorhynchus tshawytscha*) into the Hood River basin, OR, but a facility capacity of only 75,000 fish, the Confederated Tribes of the Warm Springs Nation (CTWSN) and Oregon Department of Fish and Wildlife (ODFW) needed to find an out-of-basin site to rear their supplemental fish. In collaboration with the co-managers, we designed an experiment to assess rearing effects on smolt physiology and age of maturation in Hood River spring Chinook salmon. Fish were differentially PIT-tagged and reared at three different mid-Columbia River basin hatchery facilities (Carson, Parkdale, and Round Butte) across three brood years (2008–10). We measured a variety of physiological parameters including size, condition factor, whole body lipid, growth rate, early male maturation rate, and gill Na⁺/K⁺-ATPase activity in the juveniles to rank them according to their relative "smolt quality." Smolting, size at release, and early male maturation rate varied consistently across rearing locations among years, with fish reared at the Round Butte Hatchery ranked as having the highest, and Carson Hatchery the lowest, smolt quality in all three brood years. From this assessment, co-managers were able to make a decision on where to rear their supplemental fish approximately three years sooner than if they had had to wait for adult returns. Through this study we also determined that some release groups had higher rates of early male maturation than others. The program is currently implementing a new feeding strategy based on that of naturally rearing fish, a.k.a. the "wild fish template," in hopes of further improving smolt quality in these fish. This study highlights how science can assist hatchery managers in making more informed decisions on where and how to rear their fish.

Modeling potential population-level impacts of oil spills on Pacific herring stocks in Puget Sound

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Localized oil spills that contaminate nearshore spawning areas pose a threat to developing Pacific herring embryos. Fish embryos are particularly susceptible to the developmental toxicity of oil-derived PAHs, which can be acutely lethal or, at lower exposure doses, lead to permanent changes in heart structure, craniofacial morphology, and metabolic processes that cause delayed mortality, or more subtle delayed impacts that may be associated with premature subadult mortality. A variety of localized oil spill scenarios simulating direct and delayed mortality to young of the year were used to examine the potential response of Puget Sound stocks of Pacific herring (*Clupea pallasii*). Puget Sound's remaining healthy stocks could withstand short-term impacts, but the growing number of depressed and unhealthy stocks are vulnerable to an increased risk of localized extinction. Model output predicted that for short-term, low-level impacts, the stock abundance did not exceed the natural variability observed in the population demographic data. This reveals the limited ability to observe from field observations of spawner abundance any predictions made by the model. High mortality in a single year or impacts across multiple year classes may cause stock abundance changes that exceed natural variability. Despite this, the model does indicate the magnitude of impact on the intrinsic growth rate that could reduce the productivity of affected stocks. Additional toxic endpoints and effects thresholds are currently being investigated, including sublethal impacts on cardiac function, immune function, and lipid metabolism that may all lead to delayed mortality. Characterizing these adverse outcome pathways may alter predicted impacts of oil spills on herring stocks.

Reevaluating a failed stock assessment with alternate assessment methods

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In 2017, two fully age-structured stock assessments were prepared for yellowtail rockfish (*Sebastes flavidus*) stocks north and south of Cape Mendocino (lat 40°10'N). The model for the northern stock was adopted for use in management of the stock; however, the southern model was not robust enough for management, in part due to the lack of recent age data. Lack of sufficient data for assessment is a situation common to many west coast stocks. In order to improve management in these data-limited situations, it is important to develop and evaluate alternate methods for assessment. I revisit the yellowtail rockfish assessments, comparing the results of the full assessments with those of three data-poor methods: Depletion-Based Stock Reduction Analysis (DB-SRA), Simple Stock Synthesis (SSS), and LIME, a Length-based Integrated Mixed Effects modeling approach.

Everything the same is different: Bycatch trends in the at-sea Pacific hake fishery

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A review of the bycatch trends in the at-sea Pacific hake (*Merluccius productus*) fishery seems timely given the interesting set of recent ocean conditions (the "Blob"), change in the status of several formerly-overfished rockfish species, and the record-breaking size of recent hake quotas. Rockfish, spiny dogfish, salmon, squid, and several roundfish species make up the vast majority of bycatch in the at-sea Pacific hake fishery. An inspection of rockfish bycatch trends, under recent fishery-constraining hard caps, reveals the challenges imposed by these constraints (including temporary fishery closures). Chinook salmon (*Oncorhynchus tshawytscha*) bycatch, which is closely monitored by the West Coast Region to ensure the fishery does not exceed the take threshold outlined in the Biological Opinion, shows high interannual variation. Bycatch of various round fish, including sablefish, lingcod, jack, and Pacific mackerel, show interesting cyclical patterns with sometimes-extreme variability. Finally, we have seen some incredibly rare swordfish and bluefin tuna bycatch, two species that seemed to have had temporary range extensions due to the Blob. The NWFSC's At-Sea Hake Observer Program deploys fisheries observers in the at-sea Pacific hake fleet to collect data essential to the management of this largest-by-volume fishery off the U.S. West Coast.

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